CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

VOL 2 NO 9 MARCH 1959

SPECIAL FEATURES

REGULAR FEATURES

LOOKING FOR A JOB? CONTROL *carries the best jobs going in instrument and control engineering.* **SEE PAGE 131 AND ONWARDS**

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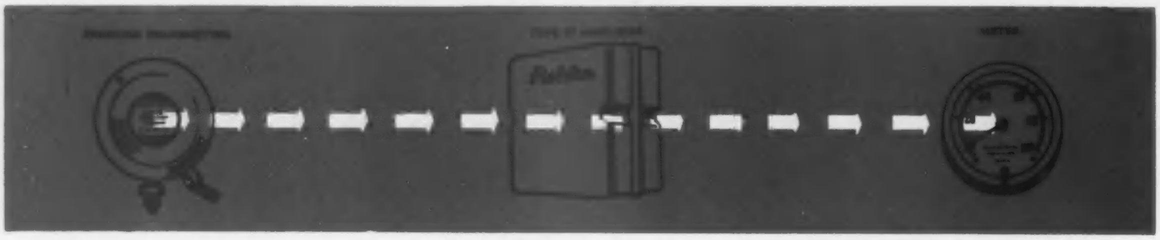
Fielden AUTOMATION

Remote Pressure Transmission



The Fielden system of Remote Indication of Pressure has all the advantages of electrical transmission and yet is so very simple.

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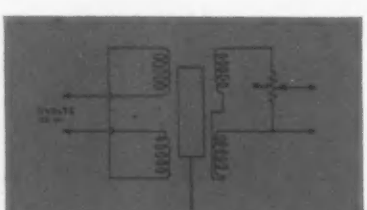
Principle of operation

In each Fielden Pressure Transmitter there is a small differential transformer and the output of the transformer depends upon the positioning of a ferroxcube core. This core is positioned by a bourdon tube, diaphragm or bellows depending upon the range. In order to simplify the equipment the differential transformer has been designed to operate on 50 cycles but the voltage is very low and the transformers can be handled, in operation, with perfect safety.



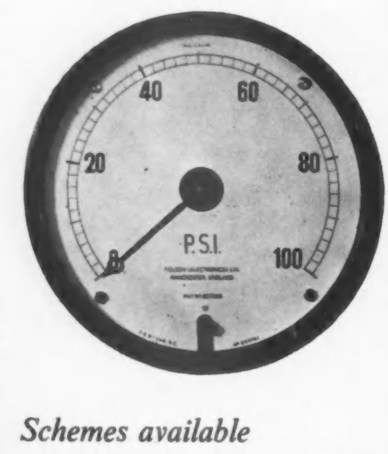
Type 'F' Amplifier

The Type 'F' Amplifier itself is a simple stable amplifier which accepts the signal from the Differential Transformer and amplifies it to the stage when it can be used for direct indication on a moving coil meter.

The Type 'F' Amplifier can be located close to the Transmitter or the indicating meter, whichever is the more convenient, and requires little or no maintenance.

Indicating Meters

Indicating Meters with 300 degrees scale, 6" diameter are available as standard, but other patterns and sizes to match other instruments are available.



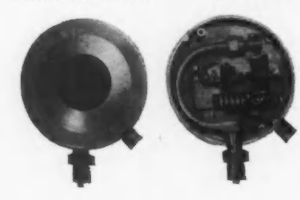
Schemes available

This Fielden pressure transmission system can be used for single point applications where one pressure is continuously indicated on one meter or a number of transmitters can be switched to one indicator.

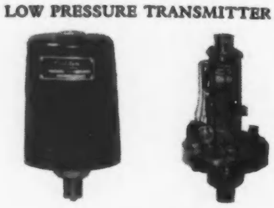
Transmitters

The High Pressure and Low Pressure Transmitters are illustrated below. These are supplied with standard B.S.P. threads and are screwed into the point of measurement. Simple electrical connections are used to transmit the information to the Indicator.

HIGH PRESSURE TRANSMITTER



LOW PRESSURE TRANSMITTER



Ranges

The minimum range of pressure for this equipment is 0–10" w.g. and the maximum standard range is 0–15,000 p.s.i. although higher ranges can be covered to special order.

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P1

PUBLISHER'S COLUMN

G.W. SWOP

Since the early days of planning this magazine we realized that guided missile control was one of the most important topics. For, quite apart from natural public excitement over the subject heightened by the lack of reliable news, much work on guided missiles is in fact control engineering. Developments are in progress at g.w. establishments which would interest and help the industrial control engineer in his work could he but learn of them. Security blankets so much British endeavour in this field that not only does it throttle outright publication of many intriguing developments, but it discourages would-be authors from writing about other unclassified developments. In addition, it slows up the delivery of manuscripts, but of course some form of g.w. security is essential. All we ask is that the authorities should give every encouragement to engineers to write about subjects that can pass the censor.

So far g.w. material in **CONTROL** has appeared spasmodically. Thus we are especially pleased to publish this month the first of an original series of authoritative articles on controlling guided missiles, which will continue regularly for most of this year. These will contain a little information not previously published but—because of security—most of them will inevitably be of a 'textbook' kind, appealing mainly to the newcomer in the g.w. field and to the engineer outside it.

Swopping control information between different types of engineer is in fact one of our principal jobs. For it becomes more and more clear that control engineering is so diverse in content and application that central services are urgently needed to help it progress in Britain. One of these is a live, informed, technical magazine to tell engineers and users what's happening in all branches of control technology. That is what we offer in **CONTROL**.

The Editor welcomes correspondence for publication.

Infra-red photocells become more sensitive

SIR: Readers of Dr Greenland's excellent article on 'Photoelectric Cells' in the February issue may be interested in two recent developments in infra-red photocells, previously unpublished, which slightly modify his Tables 1 and 2. Our indium antimonide photoelectromagnetic cells are now almost an order more sensitive than when first announced, the best cell having a noise equivalent power of $1{\cdot}2\times10^{-10}$ W. Also indium arsenide photoconductive and photovoltaic cells have been made in this laboratory with a response extending to 4 μ, a time-constant of 1 μsec and a noise equivalent power approaching 10^{-10} W. They have a similar spectral range to lead selenide cells, but are more sensitive and faster and need no protecting envelope.

I should also like to point out that the silicon photodiode should be added to Table 1. This cell, and the very similar solar battery, are available commercially here and in America, and in many applications are more suitable than the germanium photodiode.

Services Electronics Research Laboratory C. HILSUM

● *Dr Greenland thanks you for bringing these recent semiconductor photocell developments to his notice. He would also like to point out that since he wrote the article the Royal Radar Establishment has demonstrated an antimony-doped germanium cell which, when cooled to 4·2 deg K, is sensitive to beyond 110 μ*—EDITOR

Not all there: nor were we

SIR: I have read with great interest the survey of transfer function analysers, which you have published in your January issue. I notice, however, that you do not mention my company's equipment.

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Servo Consultants Ltd Z. CZAJKOWSKI

● *Sorry! When this survey was prepared we decided your instrument was too specialized for inclusion, but on fresh examination we think this was a bad decision. We are glad you have written*—EDITOR

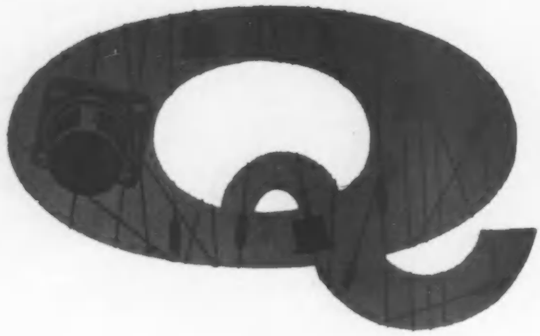
Inst. P. as overlord?

SIR: I was interested to read *Uncontrolled*'s remarks on the 'silent conflict' between the BritIRE and the IEE. This is of course merely one phase of a far wider conflict between specialization and generalization, which must occur as long as there is a desire for specialist groups within generalized groups.

For its control problems the steel industry used, until recently, only electrical engineers and fuel/instrument engineers. With the advent of electronic and control engineers, both sides have tried to claim the newcomers.

Control engineering and electronic engineering cannot stand alone and are involved in instrumentation,

Continued on page 49



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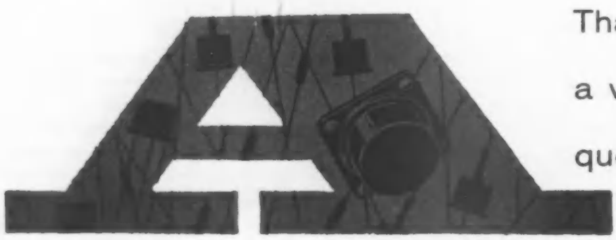

That's a very good question

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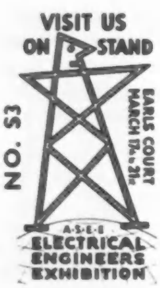

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Continued from page 47

mechanical engineering, hydraulics, pneumatics, etc. Soon each appropriate professional society will be drawn into the ring competing for what it regards as its own share of the new fields. Presumably then none of the societies will cooperate with each other. The time may well have come when the societies should meet each other to decide the spheres of their activities so that they can give a lead to industry in the solution of its problems rather than the reverse.

Finally, may I point out that in so far as engineering is applied physics, electrical engineering, radio engineering, electronics, control, etc, are all divisions of the field of the Institute of Physics, which could perhaps usefully organize the other societies.

Rotherham DERRICK SHAW

● *Uncontrolled writes:*
'I think Mr Shaw takes too critical and naïve a view of professional engineering societies. There is plenty of cooperation between them, and to suggest they are all competing for new territory is quite untrue. The IEE/BritIRE conflict is unique; one can exaggerate its importance, but it is something of which leading electronic engineers should be rather ashamed.'—EDITOR

Sales talk

SIR: In your February Leader you mention the value to industry of scientists who are—to quote your words—'caught full-time in the maw of g.w. establishments', and that much of the equipment developed has no immediate civilian application.

Should some readers have the feeling that the country's money is spent in producing a lot of by-products of research that never see the light of day I should like you to emphasize the work that is carried out by the National Research Development Corporation in that patents produced at public expense are offered to industry for sale or development.

Pioneer Designs Ltd M. D. HULL

● *Yes. Fine. And best wishes to the NRDC's new Managing Director in carrying on the good work. But you know, Mr Hull, the NRDC very rarely handles patents thrown up by defence establishments*—EDITOR

Crackers

SIR: In February (p 104) you publish what purports to be an account of equipment installed at McVitie & Price's biscuit bakery at Harlesden. Although acknowledgment is made to 'standard Henry Simon equipment', both the heading and substance of the report imply that the automatic weighing system has been recently installed by EMI. This is not only grossly misleading but inaccurate in important particulars.

The 'standard Henry Simon equipment' includes not only bulk materials handling but the automatic weighing system under Select-O-Weigh control. The Emiway equipment installed there is not an automatic weighing system nor does it perform the operations described; it is used only for recording.

Henry Simon Ltd R. C. PEATTIE

● *We regret that our report gave the impression that the EMI 'Emiway automatic weighing system' at McVitie & Price's factory actually weighs. As Mr Peattie points out, at the Harlesden installation this is the duty of the Henry Simon 'Select-O-Weigh' automatic weigher, the Emiway equipment recording the 'Select-O-Weigh' results. We were aware of this unusual arrangement but agree that the report did not make it clear*—EDITOR

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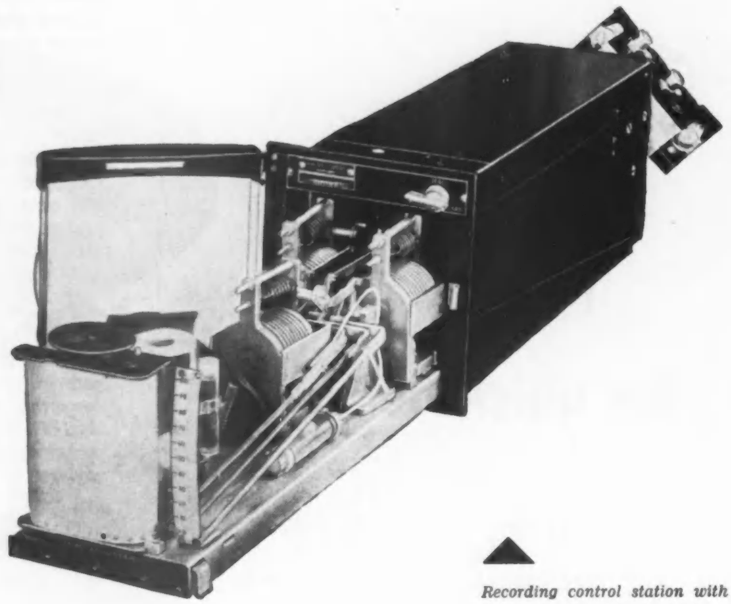
A miniature pneumatic recorder



Recording control station with chassis withdrawn. At the rear is the manifold for a 'Sunvic' plug-in controller.

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The detachable clock mechanism which facilitates chart changing

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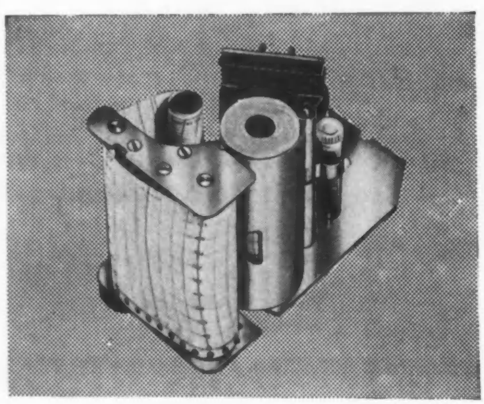

Further details in Technical Publication 1241. For a copy please contact:

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SC/76

CONTROL MARCH 1959 VOL 2 NO 9

Wanted—A National Control School

STEMMING FROM WARTIME DEVELOPMENT, SWIFT engineering advances have been made on many fronts in the last fifteen years. But none have been swifter than those achieved in the arenas of nuclear energy and control engineering. These two young subjects—dissimilar yet complementary—have this in common: they both straddle a number of well-established technologies, so that their practice demands from many of their engineers a rare breadth of outlook. Rapid development of these subjects has caught educationalists napping, and the pattern of training in both subjects in universities and technical colleges is woefully haphazard. For example, only two chairs of nuclear energy, both in London, have been established in the United Kingdom; as yet there are no professors of control engineering, and only a pittance of readers and senior lecturers.

But the development of nuclear energy has had a priceless asset in Harwell, with its liberal financial backing from the State. For Harwell has been more than a great research establishment; it has been a focal point for British work on nuclear energy, and through the Reactor and Isotope Schools has provided training at different levels for hundreds of scientists, engineers and executives. It is this lack of a focal point—whether professional society, research establishment or national college—that is bedevilling the development of control engineering in Britain. Here we use 'development' in a wide sense—the engineering development of control systems, the training of control engineers, and the awakening of industrial management to the great possibilities of automation.

This education of industrial management is vital. If automation is to be adopted by the user industries, it must be demanded by them. A great missionary drive has yet to be made on the board rooms of medium-sized firms. In these sit many decisive and financially able men, who understand milling and profiling machines, but know nothing of the electronic methods of controlling them, who employ effective inspectors but would be startled to know that ultrasonics, β-rays and photocells might do much of their work, and to whom the word 'servo' only recalls something Italian.

Both to provide the focal point and to help in educating industrial management, a new control training centre is urgently needed, and we most strongly support proposals to set up a National Control School under the Ministry of Education.

A major obstacle to wider appreciation of automation is that it is very much a fruit of the vigorous growth of electronic techniques. Application of these is largely in the hands of young engineers whose outlook and language are often unintelligible to the older 'nut and bolts' man in industry. In turn many electronic engineers cannot fully comprehend the heavy electrical and mechanical content of control engineering or the industrial processes to which their instrumentation should be applied.

The task then before a National Control School, like the Harwell Reactor School, is twofold: to give short courses about automation to executives, and to run longer postgraduate courses to engineers on control engineering and the industrial processes and techniques of manufacture to which it applies. As Dr D. B. Foster, a leading consulting control engineer, has recently put it: 'If we take automation to be a word implying "process-control", then the educational problem is to explain the new aspects of "control" to user industry, and the established aspects of "process" to the electronics industry.'

Proposals have been made by the Engineering Industries Association to the Government, the British Conference on Automation and Computation and other interested parties, for the establishment of such a school. The College of Aeronautics, Cranfield, already highly competent and experienced in teaching control, may well be the best place for it, and we understand the college authorities would welcome the idea.

The need for a new control training centre becomes more urgent every month. Immediately Government approval is given, discussions should be arranged between the Ministry of Education, and relevant trade associations, professional societies, universities and colleges, to establish it; may they proceed rapidly and the new school begin next autumn its work of high economic significance for Britain's future.

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INDUSTRY'S VIEWPOINT

A monthly article by a prominent man in the control industry on a subject chosen by himself

Leaders of the instrument industry must act now—or the industry may lose its markets, warns M. L. Jofeh, Sperry's Industrial Division Manager, in writing about . . .

FITNESS, RELIABILITY AND STANDARDIZATION

PREVIOUS CONTRIBUTORS TO THIS SERIES HAVE DRAWN attention to the important possibilities in control engineering through the application of electronics and of new materials and techniques. These possibilities include improved speed of response, greater flexibility, simplification of data-logging, on-stream measurements of variables other than temperature, pressure and flow rate, and interconnexion of control and measuring equipment with high-speed general-purpose computers. Exciting as these possibilities are, and great as their economic advantages may be, whether users accept them or not will depend ultimately on the integrity of the engineering devoted to their development.

I want to draw attention here to some less glittering but equally important aspects of control engineering.

The electronics and instrument industry has in recent years won many accolades for the freshness of its thinking and the brilliant invention. But it has not, unfortunately, a high reputation for fitness of purpose or for reliability; I hope that engineers will give much more attention to these matters in the immediate future.

I use 'fitness of purpose' here with reference to operational requirements of equipment. These include not only environmental conditions but also the means and effort available for servicing. Most factories cannot provide servicing facilities on the scale of those now available for military equipment: thus those responsible must so design and build the complex new equipment that it can be maintained and serviced by relatively unskilled technicians using simple test gear. This presents a challenge to the electronics and instrument industry which will take much thought and perseverance to master: it also requires close collaboration between manufacturers and users of control equipment, and in this connexion I welcome the recent SIMA Convention as a step towards this.

Reliability is notoriously a thorny question. To some degree it is related to ease of maintenance, as also to standardization; but the basis of reliability is undoubtedly informed design, backed by extensive environmental and life testing. Not all manufacturers have the necessary facilities, but it is vital that they thoroughly test all products before offering them for sale. Not only the manufacturer concerned but the industry as a whole suffers much harm if equipment fails on site primarily through inadequate type-testing; thus, it will be in the industry's interest if a working arrangement can be made to ensure that the facilities of some are at the service of all.

A further problem that must be solved, and solved very soon if the industry is not to harm itself permanently, is that of standardization. Over the years certain standards have evolved for pneumatic control equipment, to the advantage of both user and manufacturer. So far, no measure of agreement has been reached on standardization of electronic control equipment; manufacturers have each adopted their own standards, and a chaotic state of mutual incompatibility is rapidly arising. The major trade organizations, as well as the BSI, are beginning to look into the undoubtedly difficult problems, but I question whether they are pursuing these efforts with the vigour and determination that the urgency of the situation demands. There are two major dangers. First, if the situation persists much longer users will accumulate a sizeable investment in incompatible equipment, making later acceptance of standardized equipment more difficult. Secondly, if the British electronics and instrument industry does not put its house in order soon, not only may export to Europe be frustrated, but also its own home market may be captured by Continental firms who have already made important moves towards standardization.

The challenges and the opportunities exist; it is up to the industry's leaders to rise to their responsibilities.

Crown copyright

First of a cogent new series of articles on guided missile technology appears on p 57. **Kenneth Garner**, Lecturer in Control and Simulation at the College of Aeronautics, Cranfield, who is Consulting Editor for the series, has collected a first-class team from industry, Government establishments and Cranfield, to write on theory and practice of g.w. control. Here Garner introduces the articles.

MISSILE CONTROL

COMPLEMENTARY TO THE DEVELOPMENT OF NUCLEAR explosives, the guided missile has emerged as one of the most significant advances in the sinister art of warfare. Considered purely as a piece of engineering, it represents one of the highest forms of technological development, requiring the combination of many scientific disciplines to create it. Running through the whole complex design of a modern missile is the all-important common factor—*feedback control*. The guided missile is a supreme example of control engineering, and it is in this context that I am acting as consultant editor for the forthcoming series of articles on guided weapons. There is no intention to dramatize or popularize in these; rather we want to show how control engineering applies to missiles and in turn reveal missile techniques that can be of benefit in the non-military field.

G.W. development—the credit side

It is worth considering the real value of the guided missile. Since 1945 its development has cost the USA, USSR, and UK thousands of millions of pounds, not to say how many scientific man-hours. Of the actual weapons so far produced, fortunately only a few dozen have been fired in anger. Moreover, there is a great deal to enter on the credit side, apart from the obvious astronautical implications.

Undoubtedly the theory of feedback control has made tremendous advances owing to the urgent need to solve some very complex, and obscure, problems. Parallel with this theoretical advance, and complementary to it, has been the phenomenal rate of development of electronic analogue and digital computers. Much of the finance behind these developments has come from missile resources.

Progress in high speed telemetry and associated data-processing and recording apparatus has been greatly stimulated. Transducers of many kinds and really precise hydraulic and pneumatic control valves have been realized, to provide some outstanding equipment for direct application in factory and office automation.

Clearly more than a little has been retrieved of the vast expenditure on missile development, and there is a potential for considerable cross-fertilization of ideas and equipment between the military and non-military fields. This interchange of information will, I believe, be promoted by these articles.

Missile jargon

Like all technologies the missile field has its share of jargon, and one of the difficulties in introducing uncommitted control engineers to this subject is to make it understandable. Missile designers are usually just as much at home talking aerodynamics as they are with describing functions, or Bernoulli forces. These things,

and many others, get themselves completely intertwined in the weapon system. Special terms will normally be defined as they are used in the articles, but a few common ones are given in the short glossary on p 57, which provides a basis for talking about missiles. I have confined it to airborne weapons, which, to a large extent, cater for the popular conception of guided weapons. One should, however, not forget the seaborne guided torpedo, which is in itself a fascinating subject; but is outside the scope of these articles.

G.M. and G.W.

The terms *guided missile* and *guided weapon* are not synonymous, The former is simply a missile, peaceful or warlike, which is guided, either along a certain trajectory, or to a particular destination. A guided weapon, however, is generally accepted to mean the whole concept of the missile-guidance combination designed to perform a given warlike function, i.e. to destroy specified targets. One stage higher in the genealogical tree is the *weapon system*, which means the entire tactical, or strategic configuration and deployment of guidance systems, launching platforms and missiles.

Weapon systems

Every weapon system if defensive is the result of an assessment of the probability of defending a given friendly site or vehicle, against known aggressor targets, with the optimum deployment of guided missiles designed specially for the role. If the system is a deterrent, an assessment of the target areas and launching bases leads to the specification for it.

The weapon system itself is, therefore, the creation of politicians, operational researchers, logistic experts, and large scale system engineers. The problems which emerge from their specification are broken down into details such as size and weight of the missile to be used, what guidance (radar, infra-red, optical or other sensing device) requires development, and so on. So starts a major development programme which in general takes several years to bear fruit. In the end the public may see a missile with wings, rudders, and booster motors sprouting all over it, and inside, a labyrinth of wires, pipes, and tubes; somewhere the assembly contains a big bang. This missile is indeed the sharp end of the weapon system although representing only a small part of it.

Many targets—many designs

In warfare there are obviously a multitude of different tactical situations and of different kinds of targets. Not surprisingly, therefore, one finds many variations in operational missile design. Some are launched from the ground, others are air-launched, while others are fired from surface ships. The latest significant development is undersea launching. Some targets are stationary, while at the opposite extreme others may move at several times the speed of sound. Targets may be towns or tanks, aircraft, ships, or even foe-missiles. Thus the missile

A message from W. H. Stephens, M.Sc., F.R.Ae.S., who worked for many years on guided missile development at the Royal Aircraft Establishment, and is at present Director - General Ballistic Missiles at the Ministry of Supply

In the last few decades a remarkable development of unmanned flight vehicles has taken place, culminating in satellites and near space probes, and promising still more ambitious scientific exploration of hypersonic flight and space travel. Throughout all the stages of this progress, from the early slow-speed pilotless aircraft to the multi-stage rocket capable of reaching escape velocity, automatic control has been a fundamental requirement. In the early days it was coupled only with a simple highly stable aircraft and a preset navigation course with simple compass-monitoring. Later the task of intercepting other flying targets called for automatically controlled manoeuvres of greater and greater complexity. Thus requirements for precise closed-loop servo systems, with high frequency response and compatible with radar guidance systems, became more stringent. A typical missile is now a combination of airframe, propulsion unit and guidance and control equipment, each and all of which must work efficiently and harmoniously as part of the overall design. Only a carefully integrated missile system can execute the tasks set by interception of supersonic targets or the achievement of precise orbits in space. The physical environment of rocket flight and the necessity to obtain the maximum information from every test have led to new techniques of instrumentation and data recovery. The premium on space and weight has been a sharp incentive to miniaturization and new structural design. From all of this has emerged a vast fund of new knowledge and of new components and techniques. The series of articles on guided missile technology which begins in this issue of CONTROL *will describe many fascinating technical problems which have been met, and elucidate the interplay of various technical disciplines which combine in missile design. I hope that the techniques and components developed in the missile world will prove to have many applications to problems in civil science and technology.*

W. H. Stephens

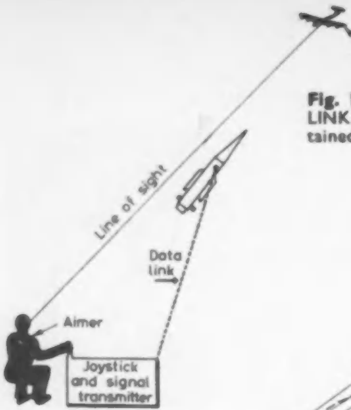


Fig. 1 TYPICAL COMMAND LINK. The missile is maintained on line of sight by aimer

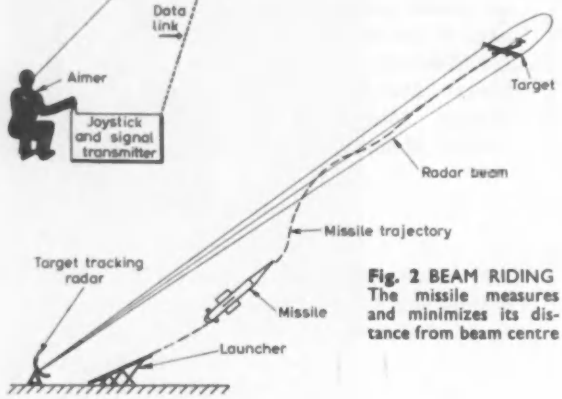


Fig. 2 BEAM RIDING The missile measures and minimizes its distance from beam centre

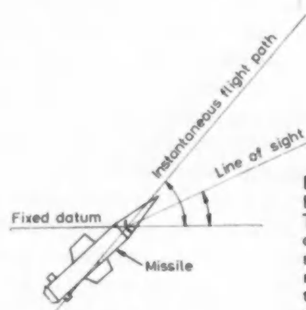


Fig. 3 PROPORTIONAL NAVIGATION HOMING. The missile measures rate of turn of sight line with respect to fixed datum, and manoeuvres so that rate of turn of flight path = constant × (rate of turn of sight line)

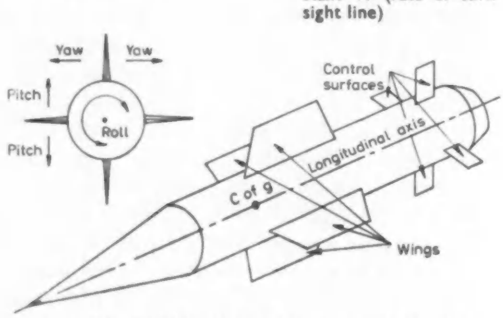
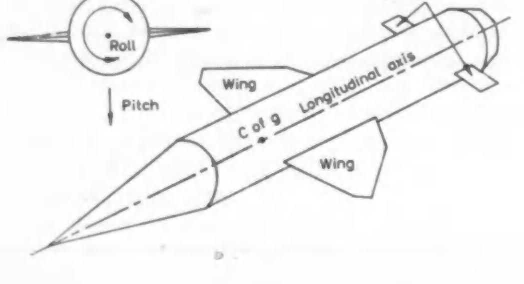


Fig. 4 CRUCIFORM (OR CARTESIAN) CONTROL CONFIGURATION

Fig. 5 TWIST-AND-STEER (OR POLAR) CONTROL CONFIGURATION



designer must do some very hard initial thinking before the general shape of the missile is evolved, and the control system specified. Unlike the industrial engineer money is not necessarily any serious handicap, so that expense in component design is not vital. However, financial expense usually goes hand in hand with the ability to reproduce the component economically in the sense of factory capacity, i.e. the availability of skilled craftsmen and materials. So the restraint is there even for military designers. This factor has led to some fine engineering achievements.

The broadest classification of missiles is into two groups: (i) *ballistic*, i.e. generally long range missiles only initially guided along a predetermined trajectory and then allowed to continue as a stone in free flight; (ii) *guided-all-the-way*, i.e. the trajectory is controlled by various means until a satisfactory interception with the target occurs. The second group may be subdivided. Missiles in it may be classified by their role, and they are defined as air-to-air, ship-to-air, ground-to-air, ground-to-ground, air-to-ground, etc. However, from the control engineering aspect the most useful classification comes from a consideration of the methods of guidance. Hence we can have a communal link missile (Fig. 1), which in its simplest form is a missile steered, through a radiated or wire link, by a human operator who can determine an error between the missile and target positions. Secondly there is the beam-riding missile (Fig. 2), which is constrained to fly up a radar beam locked onto a target. Thirdly there are homing missiles (Fig. 3), which by various methods detect the target direction and reduce the distance between themselves and the target until a satisfactory interception is achieved. There are many other methods tried and to be tried, but those mentioned are the most successful so far, and will be discussed over the next six months. Two control configurations are shown in Figs. 4 and 5.

The contributors

The authors who are contributing to this series are all actively engaged in missile work and are drawn from Ministry of Supply headquarters, the Royal Aircraft Establishment, the guided weapon industry and the College of Aeronautics. The first article, by D. W. Allen, is a descriptive one on visual command guidance systems. The second article introducing the 'aerodynamic transfer function' concept by F. R. J. Spearman, and the third on guided missile instrumentation, by M. A. Perry, will provide the basis for the rest of the series. Two other guidance systems will be dealt with in some detail in articles by J. L. Sendles and H. R. Joiner. Hydraulic missile servos will be discussed by P. D. Boyer in the sixth article, while the seventh—and probably final—article by Miss P. Hodges will be on the all-important groundwork of assessment and dynamic analysis.

In conclusion, I should like to acknowledge the co-operation and effort of the authors, who have all been most helpful in making this series a worthwhile venture.

Visual Command Guidance

by **D. W. ALLEN,**
Royal Aircraft Establishment, Farnborough

IN GUIDED WEAPON TERMINOLOGY 'COMMAND GUIDANCE' covers three classes of missile; weapons which are observed indirectly by means of radar, infra-red, etc., and steered by a human agency; weapons where the human aimer has been replaced by a computer; and those which are controlled by a human operator who observes the target visually. By far the most important group is the third, and it is with these weapons, whose guidance system includes the human eye, that this article is concerned.

Evolution of guidance systems

The earliest of all the missile guidance systems conceived by man are those employing an aimer to 'command' the direction of flight by some remote means. Anyone who has ever started a visible projectile on its way towards a target, either in anger or in play, must at times have felt a desire to control it. So it must have been through the centuries.

The problem exercised many great minds in the late eighteen-hundreds and some success had been achieved with boats and torpedoes around the turn of the century. The Frenchman Lorin proposed a guided missile for the bombardment of Berlin from the French positions in 1915, and about the same time the Germans were experimenting with a remotely controlled gliding torpedo which was launched from a zeppelin and steered by a curious system of cables and braked winches. It was very similar indeed to some of the missiles produced in the Second World War but, perhaps fortunately for the inhabitants of these islands, it was not a success.

Although by 1918 considerable thought had been

GUIDED MISSILE GLOSSARY

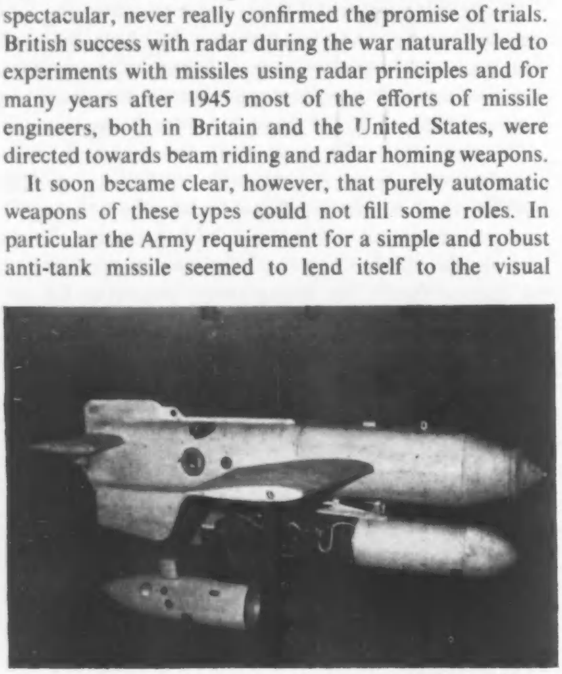
Lift	*The resultant force acting on a wing surface or body normal to the airstream arising from its motion relative to the surrounding air* NOTE.—*Lift is not necessarily directed in opposition to gravitational force but can act in any direction depending on the shape and motion of the wing surface or body*
Drag	*Resultant force in the direction of the airstream opposing motion*
Incidence	*The angle between a defined axis in the wing or body and the relative direction of the airstream. For zero incidence there is zero lift*
Aerodynamic derivative	*Partial derivative of any output for any input in aerodynamic terms. Usually expressed as force or moment per unit wing deflexion, sideslip velocity, etc*
Cross-coupling effects	*Forces acting on an airframe in one plane of reference induced by motion in an orthogonal plane*
Malalignment *or* **Misalignment**	*Imperfections in the symmetry of the airframe causing disturbing forces when all control surfaces are set to nominal centre*
Control surface	*A wing surface which can be deflected to provide an aerodynamic lift force at a point on the main airframe. Variously called* rudder, elevator, aileron, *depending on whether its function is to yaw, pitch or roll the missile*
Lateral acceleration **Lateral velocity** **Lateral displacement**	*Motion in a plane perpendicular to the longitudinal (fore-and-aft) axis of the missile*
Flight path	*Trajectory of the centre of gravity of the missile*
Standard atmosphere	*A fictitious mean atmosphere used as a basis for aerodynamic calculation*
Autopilot	*Any flight and command data-handling device whose output manoeuvres the airframe to some desired condition*
Trim	*The attitude of the airframe for any fixed setting of its control surfaces*
Weave motion	*The relatively slow oscillation of the centre of gravity of the missile about a mean trajectory*
Weathercock oscillation	*A rather faster oscillation of the fore-and-aft axis of the missile about the centre of gravity with respect to a trim condition direction*
Cruciform missile	*A missile airframe having two pairs of wings at right angles. Can move in any direction laterally without the need to roll*
Twist-and-steer *or* **polar missile**	*A missile air frame having only one pair of wings and needing to roll before moving laterally along a given direction*
Noise	*Any extraneous signals which can appear in the various control loops. Generally, guidance radar noise is meant*
Boosts	*Auxiliary motors used during the launching phase and usually discarded when burnt out*
Miss distance	*The minimum achieved separation range between target and missile during an interception*

given to the mechanics of controlling the flight of a missile, little or none had been given to the difficulties involved in guiding it towards a particular target. It seems to have been generally assumed that once the control surfaces could be moved from a distance the problem was solved and the missile would be able to proceed unerringly to its prey. This assumption was not borne out in practice.

Except in the limited field of target aeroplanes little progress appears to have been made between the wars, although autopilots came in for some intensive development which resulted in the unguided autopilot-controlled Larnyx flying bomb and the 'Queen' series of radio-controlled targets.

During the Second World War the Germans achieved considerable success with the remote control of bombs and missiles but their performance in action, although spectacular, never really confirmed the promise of trials. British success with radar during the war naturally led to experiments with missiles using radar principles and for many years after 1945 most of the efforts of missile engineers, both in Britain and the United States, were directed towards beam riding and radar homing weapons.

It soon became clear, however, that purely automatic weapons of these types could not fill some roles. In particular the Army requirement for a simple and robust anti-tank missile seemed to lend itself to the visual



Courtesy Interavia

Fig. 1 The German Hs 293 glider bomb, used towards the end of the war. The weight was rather more than a ton, and the wing span about 12 ft

command principle: while the possible use of wires to carry the control signals could mean freedom from radio counter-measures.

General principles

Most of the early attempts to guide missiles by remote control were made on the assumption that the device could be made to fly along a devious course, around obstacles and over hills and finally to dive directly onto its objective. Unfortunately flights of this nature require an accurate knowledge of the range of obstacles, target and the missile. Without this knowledge the necessary manoeuvres cannot be performed.

It was some years before the principle of line-of-sight control was proposed. It is not clear who first made the proposal although very probably it was Professor Herbert Wagner. The principle is that if a missile proceeding away from the controller be brought to, and held on, a line of sight between the eye of the controller and the intended target it must inevitably hit that target. No knowledge of target or missile range is required for guidance, although with a practical missile of limited speed and time of flight some knowledge of target range is required for fire control.

Using this principle, and missiles with flares attached to increase their visibility, the Germans soon found that they could hit targets at long ranges with considerable accuracy. If the aimer was expert he only needed to see a target to be able to hit it. Trials results were extremely

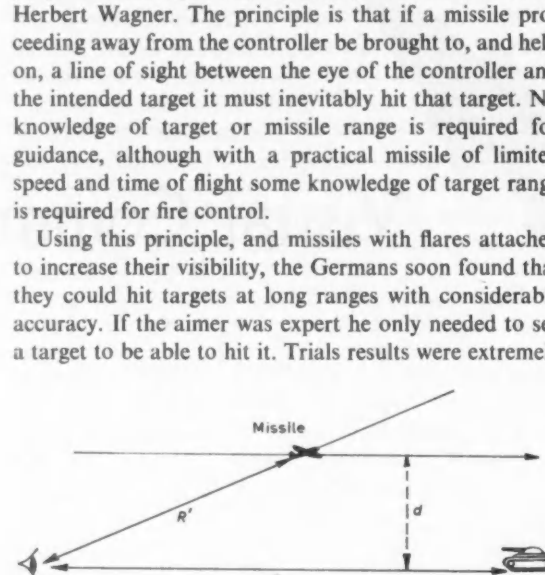


Fig. 2 The aimer's job is to move his missile a lateral distance d onto the line of sight of the target. What control law should govern lateral acceleration of the missile in terms of movements of his control stick?

encouraging although performance in the field was often disappointing. It became apparent that a very high standard of training had to be maintained to avoid poor results. Wagner, in a lecture in 1944, considered that the task of the aimer was too difficult and must be simplified; he also thought that certain improvements could be made in the missile which would result in a faster response to the operator's control demands.

The Germans use visual command control

Visual command control was first applied to air/surface missiles, notably the FX 1000 free falling bomb, and the Hs 293 anti-ship glider bomb (Fig. 1). Later, when the tide of war was turning, the same guidance principles were applied to surface/air weapons such as the Hs 117 'Schmetterling' and the Messerschmidt 'Enzian'. Considerable progress was also made with air/air missiles, the most interesting of which was the Ruhrstahl X–4, which was an attempt to make a cheap, simple weapon of high accuracy. The cruciform wings of this missile were of plywood and control was effected through spoilers fitted to the pressed metal tail surfaces. To reduce the effect of aerodynamic asymmetries the missile was allowed to roll at a few cycles per second and the control signals routed to the correct spoilers through a gyro-mounted commutator. A development of this missile, the X–7, intended for anti-tank use, had reached the early trials stage by the end of the war. However, the end of the war was not the end of the German work, since the French, who had been building parts of the X–4, themselves developed from it the very successful SS 10

anti-tank weapon. This retained the free rolling characteristic and spoiler control of the X–4 and the guidance link was also wire, but the aerodynamic configuration was very different.

Types of control

All the missiles so far mentioned were fitted with simple control systems, in which a movement of the control stick produced a proportional control moment in the appropriate plane: this in turn resulted in a missile lateral acceleration. Consideration of Fig. 2, however, will show that this type of control law is not necessarily the best for ease of operation. In the figure, R' is the range (for the moment assumed fixed) from operator to the target, R the range from operator to missile and d the distance of the missile from the aimer/target line of sight. In order to gather the missile onto this line of sight, the operator must make the necessary control movements to move the missile laterally the exact distance d. With a control law that results in missile lateral acceleration proportional to control stick movement, he must make four discrete control stick movements; one to apply lateral acceleration, one to remove the acceleration and maintain a lateral velocity, one to apply acceleration in the opposite sense to remove the lateral velocity, and finally one to remove that acceleration when the lateral velocity and the distance d are zero. These control movements must also be timed accurately if overshoots are to be avoided.

Stationary targets

For stationary targets at fixed ranges a control system resulting in lateral displacement proportional to joystick movement would appear to be simpler for the operator,

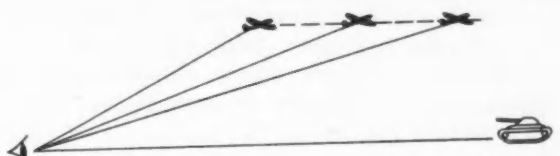


Fig. 3 A missile moving along a track parallel to the target line of sight appears to the operator to be closing the target

since only one discrete movement proportional to the error would be required to bring the missile onto the sight line. This is an over-simplification in practice, for the missile is at all times moving away from the operator, and will, if it continues along a track parallel to the line of sight (Fig. 3), already appear to the operator to be moving towards the sight line; thus the amount of joystick movement required is proportional to range. Also with a moving target, the aimer would need to match its motion with an appropriate movement (allowing for target movement and missile range) of the control stick.

Consideration of these difficulties suggests that a control law giving a lateral velocity proportional to control stick movement might be the best compromise, and for an ideal missile this is in fact so. But real missiles are not ideal and modifications are usually required to the basic control law for practical reasons. How then is the choice of control system made?

The influence of simulators

With any missile system, trials in the field are expensive and time consuming. Probably visual command control would never have been developed to its present state if it were not for the electronic analogue computer, used in the special form of a missile simulator. This device enables engineers to set up the characteristics of the particular missile being simulated (or its estimated characteristics if it does not yet exist) and try out different forms of control. They are thus able to evaluate the merits of the basic forms and combinations of these forms. Research soon confirmed that a development of the basic velocity control system gave the best results for anti-tank missiles, taking into account the relatively short time available to the operator to carry out his task and the fact that long periods might elapse between practices.

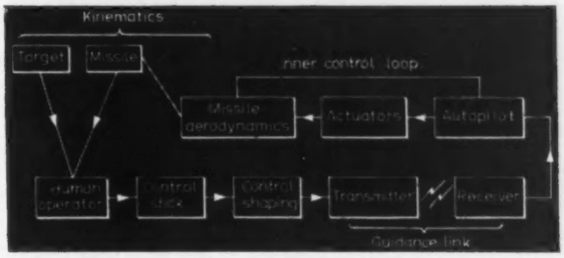


Fig. 4 The main elements that make up a visual command control system

The simulator also proved invaluable as a training aid: operators could be brought up to a high standard of aiming accuracy before being allowed to fire a real missile, and then kept in training in the same manner as aeroplane pilots. Further investigation showed that considerable gain in accuracy, at the expense of missile complication, resulted from fitting an autopilot to reduce the effects of aerodynamic asymmetries. Whether or not it is in fact fitted to a particular missile depends on logistic considerations.

A block diagram of the major components of a visual command control system is given in Fig. 4 and we shall now consider the characteristics of these components separately.

The human operator

We hear a great deal nowadays about the limitations of man, but consideration of his accomplishments indicates that he does still possess certain advantages over machines. Not the least of these is his ability to observe, evaluate and decide.

Vision

Of direct interest is visual acuity; there are many different measures of this but those most relevant to control and tracking tasks indicate that an operator with

normal eyesight has no difficulty in resolving an angular error of 1 min. If the target is viewed through a magnification of only six times the detectable error is reduced to 0·15 min. Optical imperfections will increase this figure somewhat but the acuity will still be high compared with radar and other automatic methods. Of almost equal importance is form perception. This is an ability found only in the higher living organisms; for certain tasks requiring target recognition, the selection and tracking of one of many targets and the direct identification of friend or foe, there is no adequate substitute for the human eye.

Although vision is restricted to moderate ranges and to conditions of clear daytime visibility, the visual sense is not subject to certain confusions that can seriously affect radar performance. Whereas to the eye a tank is recognizably different from a small hill or a pile of scrap iron, this is not always so with radar.

The man-machine system

Fig. 5 shows a representation of the man-machine system*. The man is represented by the boxes above the thick black line and the machine by those below. The central nervous system consists of the brain and spinal cord. It is through the activity of this nervous system that thought and learning take place and decisions are made. At the bottom of the diagram is the machine, showing the input and output. The nature of these depends, of course, on the machine being controlled.

It would be very convenient for control system engineers to be able to write down an equation representing the transfer function of this man-machine system, since it would then be possible to design the machine part

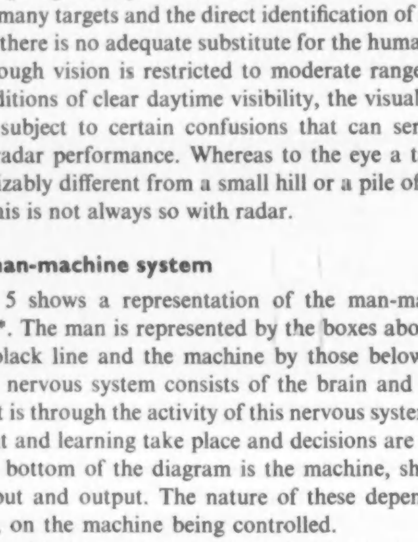


Fig. 5 Man and machine form a closed loop

to complement the man and achieve high precision and stability. Two difficulties frustrate such a mathematical analysis.

Intermittency

Whenever a human is called upon to respond to some transient, there is a pause before any response is forthcoming; this pause is known as the reaction time and can vary within wide limits. It usually averages 0·3 sec. Evidence suggests that as a result of this delay human response is intermittent rather than continuous.

* Birmingham, H. P., and Taylor, F. V.: 'A Design Philosophy for Man-machine Control Systems', *Proc. Inst. Radio Engrs.*, 1954, **42**, p. 1748.

Adaptability

Secondly, and more important, man appears to have several transfer functions which he can select and modify to suit the task with which he is confronted.

In spite of these difficulties several attempts to describe man as a linear system have been made. The results of such studies are of very limited application and great care should be exercised in using them. For instance, one such analysis proves conclusively that a man cannot fly a helicopter; fortunately the people who fly them are unaware of this.

One must then fall back on the empirical approach, and adapt the simulator to investigate the man as well as the machine. In practice a number of difficulties arise owing to the human's ability to modify his transfer function to suit the problem. When a gain in a control system is changed, the operator will, after a short period of learning, modify his own gain to compensate, or if a stage of integration is inserted before the machine he will obligingly perform a differentiation.

Such flexibility has, in the past, been very useful to the control system engineer since he could rely on the human to make the most of any control system, no matter how inadequate. This is probably the most important reason for using men in control loops. Sometimes this blind reliance on the adaptability of man has resulted in very badly conceived control systems.

Control sticks

In all the early command guided missiles the control input devices were large and cumbersome, sometimes even taking the form of handwheels. Nowadays it is usual to make very small control sticks which can be operated by the fingers or thumb. Thumb joysticks in particular are very popular and, perhaps surprisingly, permit smooth and delicate control.

Control shaping networks

A most important part of any missile command control system is the shaping network. In this the conversion from the fundamentally acceleration response of the missile to a velocity or displacement control is usually effected. Clearly, in an acceleration system, if a simple passive differentiator is connected after the control stick, movements of the stick will result in proportional missile lateral velocities, always providing that the system remains linear. Fig. 6 will make this clear. The passive differentiator, or phase-advance network, is one of the simplest, and various arrangements, some active and incorporating limits and non-linearities, are used for differing control tasks.

Guidance links

Much of the early work on remotely controlled vehicles was carried out with radio links, although, as

mentioned earlier, the Germans had experimented with a crude wire link as far back as the First World War.

Wire links

The first successful use of wire-laying missiles was during the Second World War. A wire link was developed for the Hs 293 glider bomb for use if the radio became subject to allied jamming but it was, in fact, never used operationally. This is surprising since the allies claimed to have successfully jammed the control of the Hs 293 glider bombs used against the Mediterranean convoys, by transmitting signals recorded during previous attacks.

All the German wire links employed two single-strand enamelled steel wires usually dispensed from bobbins mounted on the missile wing tips. This arrangement is still used by the French missiles although it is now possible to use single bobbins of multi-conductor cable, which enables pitch and yaw control signals to be kept separate. With two-wire systems some form of multiplexing must be used.

It must be stressed that, in flight, the missile lays the wire from a bobbin mounted on, or in, the missile and does *not* drag it from the ground. The wire is stationary with respect to the ground and the extra drag experienced by the missile is only that necessary to unreel the wire from the bobbin: usually a matter of two or three pounds.

As the weight of missile borne equipment is about the same for wire or radio links, the biggest single factor affecting the choice of wire is usually security. There is as yet no known way of interfering with the control signals short of cutting the wire.

Radio links

The advent of multi-channel proportional radio links is comparatively recent; before 1939 most radio control systems worked on the 'black-white' or 'on-off' principle and this was one of the main reasons why autopilot control of target aeroplanes was necessary. Without an autopilot, corrections for disturbances due to external factors such as bumps have to be made via the radio link and this is not possible with a link that is only capable of passing relatively crude information at a low rate. If an autopilot is fitted it is only necessary to transmit the information necessary for long-term monitoring of the flight.

One of the more popular radio control systems is that in which a high audio frequency sub-carrier is allocated to each control channel. The control information is impressed on the sub-carrier by some form of time modulation. Frequency or phase modulation is often used, although the sub-carrier may be simply switched on and off at a few tens of cycles per second and the mark/space ratio of the switching made proportional to the control information. Whichever method is employed the main radio frequency carrier is finally modulated by the sub-carriers; usually on a time-sharing basis.

Because of the danger of electronic counter measures the airborne receivers are usually of narrow bandwidth and relatively insensitive: transmitter powers are consequently rather high, which makes for bulky ground equipment.

Another disadvantage of radio links is the necessity of providing different radio frequencies, at least for adjacent missile sites, with the attendant supply problems. On the other hand, after the engagement is over, no tell-tale wires are lying across standing crops and pointing back to the launch position.

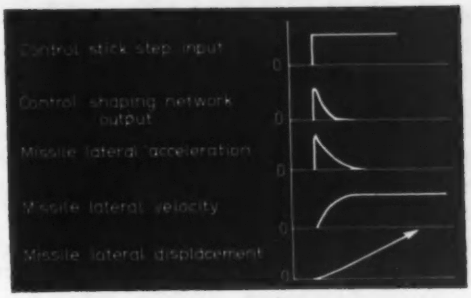


Fig. 6 Showing how a differentiator can ensure that control stick movements result in proportional missile lateral velocities

Missile aerodynamics

All early missiles were of conventional aeroplane shape, and not until the Second World War were the advantages of cruciform construction realized. The disadvantage of the aeroplane configuration is that, since lift can be generated only in a plane normal to the wings, the missile must first be rolled before a large lateral error can be corrected.

As far as aerodynamic controls are concerned, the conventional tail surfaces can introduce an acceleration lag into the system, since, particularly in subsonic flight, there may be an excessive time delay between the application of control moment and the build-up of the required acceleration. This is because the whole missile must pitch or yaw in order to produce the necessary wing incidence.

Fixed tail surfaces and moving wings can realize a considerable improvement, for then the incidence is controlled directly. There are several intermediate possibilities such as the use of flaps or spoilers on the wing itself, instead of on the tail, or the use of jet deflexion to produce a rapid build-up of body incidence: nose controls, too, give some improvement.

Stability of the missile is of great importance, but must not be obtained at the sacrifice of manoeuvrability. For this reason artificial stability in the form of an autopilot is often introduced. Dihedral cannot be used for roll stabilization as demands for an acceleration of more than 1 *g* downwards would cause the missile to roll over. Roll stabilization can be dispensed with and the missile allowed to roll freely if the control signals can be commutated to the appropriate control surfaces while the missile rotates. This method has the additional

advantage that various aerodynamic asymmetries tend to cancel themselves out.

Anti-tank missiles always operate near sea level and their speed is subsonic in order to give the aimer adequate time in which to carry out his task of aiming; so it is usual to find that they have thick stubby wings with swept-back leading edges and rather blunt-nosed bodies.

Autopilots

Missiles fitted with autopilots are usually referred to as having closed loop control systems because a subsidiary inner feedback loop is closed through some sensing element such as a gyro; thus demands sent through the guidance link are normally for heading angl^ or heading angle rate, depending on the type of instrument used. Open loop control systems are those in which the demand reaching the missile is always for control surface angle.

Most command controlled missile autopilots use gyros in some form or another. Cordite-fired and clockwork instruments have been used, as well as the normal air-driven and electric types.

Actuators

Control surface actuators usually follow the conventional pattern of pneumatic or hydraulic rams acting on the surface through a lever, although nowadays cordite gas* is often used to pressurize the hydraulic fluid or even to power the actuator directly.

Weapon systems

Even when all these component parts have been brought together the resulting weapons system is relatively simple. Attempts to fulfil too many requirements can add considerable complexity, but the basic simplicity makes visual command guidance attractive for many roles and a number of interesting missiles using various combinations of the possible aerodynamic configurations and control and guidance systems are now coming into service.

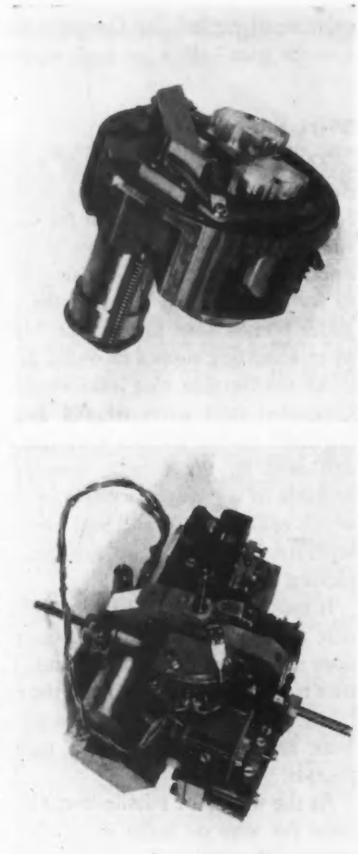


Fig. 7 Parts of the Vickers 891 anti-tank weapon

a The gyroscope assembly, comprising two datum gyroscopes, with blast run-up coasting rotors. The cordite cylinder with its safety springs can be seen on the left of the picture.

b The control surface actuator assembly showing the differential electromagnetic relays controlling the flow of gas to the actuator pistons

Courtesy Vickers-Armstrong (Aircraft)

CURRENT COMMAND GUIDED WEAPONS

Here are some notes on current visual command weapon systems developed by the Western powers.

United Kingdom

It is not possible to give many details of the control and guidance systems of current British command guided missiles although two representatives, the Vickers 891 (see Fig. 7) and the Pye anti-tank weapons, were on view at the 1958 Farnborough Show. Both these missiles use wire guidance links and both are of cruciform construction; but whereas the Vickers 891 is controlled by flaps on the wing, the Pye uses jet deflexion. Joysticks differ in detail but are both thumb operated and optical magnification is available for long-range targets.

United States

The United States armoury includes two very interesting visual command guided weapons, Bullpup and Dart, differing from each other in almost every respect but guidance.

Bullpup. This is an air/surface weapon for use against tactical targets. It has been described as a 250 lb bomb with minimum propulsion, guidance and control. Bullpup is a tail-first cruciform missile and flies at about Mach 1·8. Aiming is carried out by the pilot of the launching aircraft.

Dart Although considerably larger than the Vickers 891, Dart has a similar role: the highly accurate delivery of an anti-tank warhead. It is a cruciform missile controlled by flaps on the wings and tracked through an optical system designed by Professor Wagner, who was responsibe for the German Hs 293. The guidance link is wire and the speed subsonic.

France

SS 10. The SS 10 is one of the cheapest guided weapons available today and can be used from helicopters, from light aircraft or by foot soldiers against tanks or other hard-skinned targets. It is a cruciform tailless missile controlled by spoilers on the wings, and is allowed to roll freely during flight.

SS 11. This is a development of SS 10 and is generally similar to it. It is, however, controlled by jet deflexion and has quite highly swept wings.

SS 22. The latest of the French family of small weapons, the SS 22 differs from its predecessors by having radio guidance in place of wires.

Nord 5103. This is an air/air weapon very similar to the SS 22. But it is considerably larger than the anti-tank weapons and is supersonic.

Switzerland

Cobra IV. The Cobra IV is a roll stabilized development of the Cobra I and is a tailless cruciform missile very similar to SS 10. Guidance is through a wire link.

Sweden

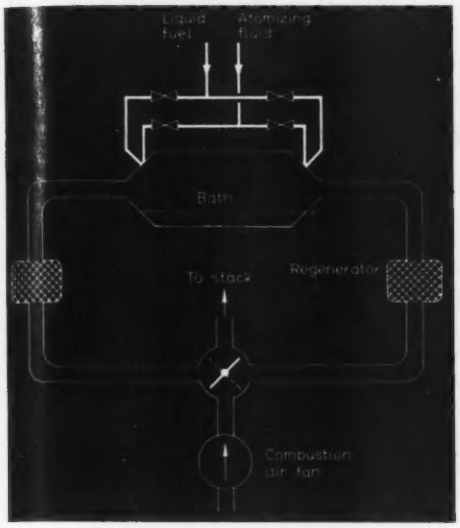
Robot 304. Very little information is available on this air/surface weapon except that it is radio command guided and has nose controls.

This short list of command guided weapons is by no means complete but it will serve to show that, after a period of indecision, this type of missile has come back into its own and that even in the g.w. field man has not yet been entirely superseded by automata with electronic brains.

* *cf.* Garner, K. C.: 'Missiles—the power to guide them', *Control*, 1958, 1, August, p 64.

Regulating the open hearth furnace

Addressing the busy engineer, George Kent's K. A. Steele highlights the main instrumentation and control techniques in open hearth steel manufacture



1—Combustion air preheating by furnace reversal

The open hearth furnace can be fired with either liquid or gaseous fuels, or a mixture of both. The combustion air is preheated by passing it through regenerators built below, and at either end of, the furnace. The operation is cyclic, air being fed in via one regenerator and the hot combustion gases exhausting through the other; the furnace is then fired from the other end, so preheating the combustion air. When gas (other than coke oven gas) is fired, the regenerators are partitioned into separate chambers so that the gas may also be preheated. Fig. 1 shows the layout of a liquid-fuel-fired furnace.

Fig. 1 Plant layout for liquid-fuel-fired furnace

Open hearth furnaces vary in capacity, normally between 30 and 350 tons.

2—Furnace roof temperature control using radiation pyrometry

The first element of automatic control in the open hearth furnace involves the measurement of roof temperature. One, two or, occasionally, three radiation pyrometers, according to the size of the furnace, are continuously sighted on to the furnace roof; the pyrometer detecting the higher temperature is used for control and identified by a pilot light.

In the arrangement shown in Fig. 2 the higher temperature only is recorded, but another system provides a record of the temperature detected by each pyrometer. Three-term control action is necessary, and ancillary equipment must be introduced to overcome the effect of integral saturation due to a drop in temperature during, and immediately after, a furnace reversal.

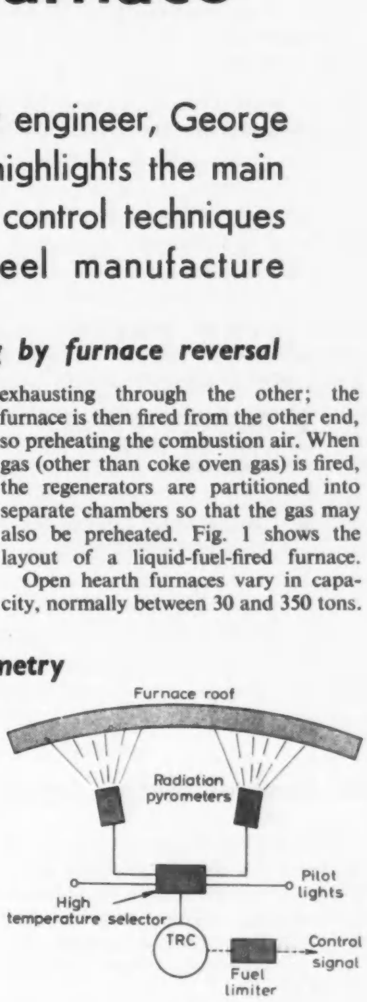


Fig. 2 Roof temperature control circuit

3—Combustion control depends on rate of fuel input

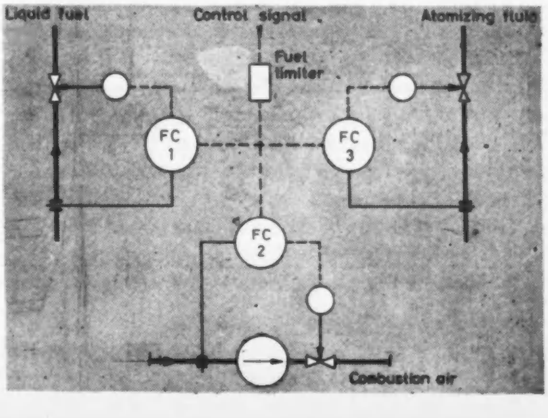


Fig. 3 Combustion control circuit for liquid fuel firing. FC1, oil flow controller; FC2, air flow controller; FC3, atomizing fluid flow controller

The output from the temperature controller is a heat demand signal and is, therefore, used to establish the rate of fuel input. Flows are controlled to this value, subject to any limitations which the furnaceman may impose. The liquid fuels commonly used are pitch creosote, C.T.F., or the heavy base oils having high viscosities and, consequently, flow measurement is carried out at the atomizing temperature for the fuel. Combustion air and

atomizing fluid—usually steam—are measured and flow-controlled in a definite, but adjustable, ratio to the fuel control rate. To cater for the differing fuel/atomizing fluid ratios during melting and refining, this adjustment is often made external to the instrument. Fig. 3 is a combustion control circuit for liquid fuel firing.

Furnaces are often fired with a mixture of gas and oil and Fig. 4 shows a combustion control circuit for such mixed fuel firing. Fuel input rates can vary over quite wide limits and the controls must be designed accordingly. These limits can be reduced for a particular set of conditions, but the arrangement of Fig. 4 covers many possible variations. Gas flow rate is controlled according to heat demand, and is also transmitted to a subtractor relay, whose output signal represents the contribution oil must make. The system is self-compensating for changes in gas availability, and this results in more stable control of furnace roof temperature.

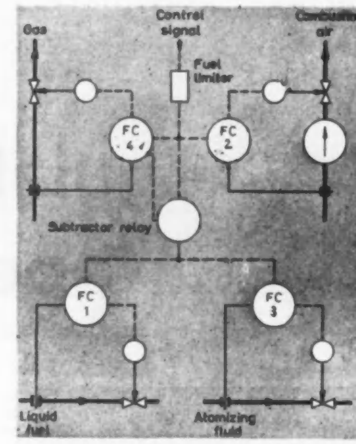


Fig. 4 Combustion control circuit for mixed fuel firing. FC1, oil flow controller; FC2, air flow controller; FC3, atomizing fluid flow controller; FC4, gas flow controller

4—Pressure control prevents cold air ingress to furnace

STOP PRESS

latest developments provide

★ *Measurement of oxygen in waste gas ahead of the regenerators*

★ *Close control of distribution for twin-burner operation*

★ *Instrumentation of oxygen flow in oxygen lancing*

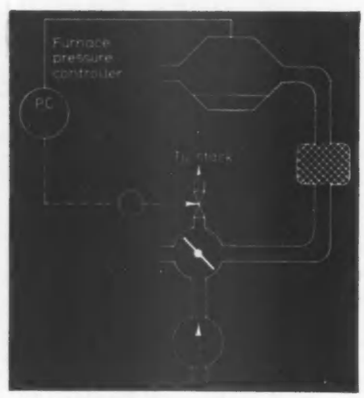


Fig. 5 Furnace pressure control circuit

Furnace pressure is measured by taking a tapping in the furnace crown and is regulated by a damper on the waste gas outlet. A second line is taken to the instrument to compensate for buoyancy effects caused by the high ambient temperature surrounding the furnace. A furnace pressure control circuit is given in Fig. 5.

Pressure control has a twofold purpose: it prevents cold air ingress, through doors etc., which would otherwise chill the furnace and cause oxidization; and it helps stabilize the geometry of the flame so that maximum heat is transferred. The pressure must be very slight in order to prevent flame 'sting-out' when the doors are opened.

5—Reversal control depends on time and/or temperature

The furnace is reversed on a time and/or regenerator temperature basis, either by hand or automatically using sequence controls. Fig. 6 shows reversal control and includes oxygen-in-waste-gas circuits. A simplified, typical sequence would be:

1—Detection of high regenerator temperature

2—Lock instruments in position to speed up resumption of stability after reversal

3—Close oil valve N1

4—Close steam valve N2

5—Reverse position of combustion air/waste gas valve.

6—Open steam valve S2

7—Open oil valve S1

8—Unlock instruments

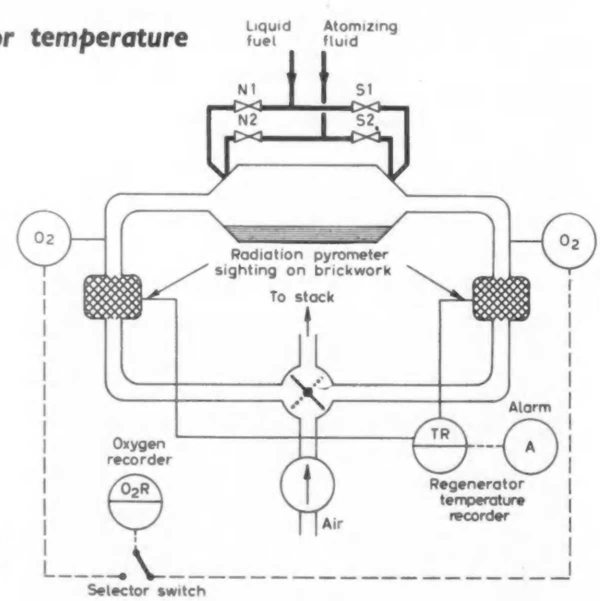


Fig. 6 Reversal control and oxygen in waste gas circuits

The last part of an article reviewing the methods used in automatic inspection

Replacing the human inspector—3

by **PETER D. ATKINSON, M.A., A.M.I.E.E.**
Measurements Division, Tube Investments Technological Centre

MATERIAL QUALITY (*contd.*)

Electromagnetic methods can be conveniently divided into those which depend primarily on the magnetic properties of the material, and those which depend on the electrical resistance of the material.

Magnetic methods

One method of detecting cracks in a magnetic material consists of magnetizing it, usually by means of an electro-magnet, and applying a powder of magnetic material or a suspension of such particles in a suitable liquid. The magnetic particles collect at cracks which break the surface and which lie transverse to the magnetic field, because the field at the surface is distorted by the crack. The conventional technique depends on a careful visual examination of the part to find the powder indications, and although equipment has been built in which a fluorescent magnetic ink is used and the indications are detected by means of a photoelectric cell the idea has not been widely used. An alternative to the use of magnetic particles to detect the disturbance in the field caused by the crack is to scan the surface with a magnetic detector. If the magnetizing field is an alternating one then a simple coil system can be used for this purpose and the basic arrangement is shown in Fig. 13.

The main difficulty experienced in using the magnetic effect for the detection of cracks arises because the properties of magnetic materials are very much affected by mechanical work and by small changes in composition. As a result the properties may vary appreciably within a single piece or component, and the distortion of the field caused by these local variations is, in a practical instrument, almost impossible to distinguish from those due to cracks. The only satisfactory way of overcoming this difficulty appears to be to apply a powerful polarizing field to the specimen in order to produce magnetic saturation, thus rendering it non-magnetic for the purpose of the test. The methods used with the polarizing technique are then based on the resistive effect.

The sensitivity of the magnetic properties of many materials to composition, heat treatment, and mechanical work makes magnetic methods suitable for checking these parameters. The method is to surround the part with a coil carrying alternating current and measure its electrical impedance. The most convenient way of making the measurement is to use a comparison circuit in which there are two similar coils; in one is placed a standard, i.e. a part known to be correct, and in the other are placed, in turn, the parts to be checked. The unbalance of the bridge is then a measure of the difference between the magnetic properties of the standard and the other parts. If the manufacturing processes are such that only one property which affects the bridge balance can vary then the bridge output voltage is used to operate an alarm when the parameter concerned falls outside pre-determined limits. If, however, more than one parameter is liable to vary and only one is significant it becomes difficult to avoid rejecting a proportion of good material. It is sometimes possible to distinguish between different parameters by examining either the phase or the wave-form of the bridge output voltage; phase discrimination can be performed quite readily by automatic circuits, but the use of waveform has generally been restricted to manually-operated instruments where a man can observe the waveform on a cathode ray tube. This test method is extensively used for checking the analysis of steels and the heat treatment of components.

Electric resistance methods

In some non-ferrous metals, in particular copper, measurement of electrical conductivity is used as a means of sorting material by alloy or impurity content (*8*). The most convenient methods for automatic measurements are those based on inducing alternating currents into the material. Measurement of thickness by this technique has already been discussed. The same methods can be used for conductivity measurement provided that the effect of thickness is eliminated. It has been explained how, in round sections, this can be achieved by frequency discrimination (Fig. 9).

In the case of flat sections a modification of the single coil method of measuring thickness is used. If the frequency of the excitation current is high enough, the alternating field is so greatly attenuated at the remote surface of the material that small changes in thickness have negligible effect and the coil impedance is only affected by conductivity and the spacing between the coil and the near surface. It is possible to eliminate the

effect of small variations in clearance between the coil and the specimen, by a technique closely analogous to that used for separating the effects of conductivity and diameter in round sections.

Crack detection is another important application of eddy current techniques (*9*). Cracks in metal almost invariably present a high electrical resistance to currents flowing across them and they thus distort the pattern of induced currents. Two methods are used to detect the changes in current distribution caused by a crack; either the change of impedance of the energizing coil is measured, or the field due to the disturbed field is detected by means of a separate detector coil or a combination of coils (Fig. 14).

The distribution of current is also affected by the dimensions of the part and by the electrical conductivity of the material. Fig. 9 shows how the phase of the impedance of a coil loaded by a piece of conducting material is affected by the conductivity of the metal and by the diameter. The presence of a crack has an effect similar to that of a change in conductivity, and so by a suitable choice of frequency it is possible to distinguish between cracks and dimensional changes by phase discrimination. Phase discrimination cannot normally be used to eliminate the effect of changes in conductivity which may occur due to changes in composition. The use

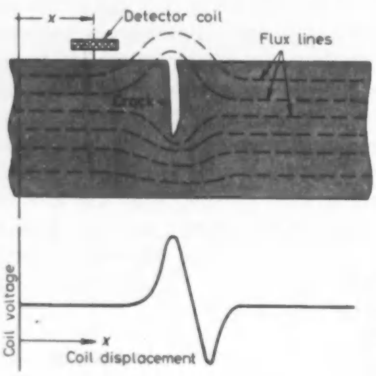


Fig. 13 Magnetic crack detection using alternating flux and detector coil

of separate detector coils offers a way of eliminating the effect of gradual variation in dimensions and conductivity.

Electromagnetic methods can only be used to examine materials of limited thickness, because the induced currents which are used to explore the material only penetrate to a limited depth beneath the surface (Fig. 15).

In Fig. 15

$$K = 1{\cdot}11 \times 10^{-4}\, a \sqrt{\left(\frac{\mu f}{\varrho}\right)}$$

where μ = permeability, c.g.s. units
ϱ = resistivity, ohm-cm
a = radius, cm
i = current density
f = frequency, c/s

The electric resistance method of crack detection is widely used in automatic inspection of non-ferrous bar, tube and sections for longitudinal cracks. It has the advantages of being very sensitive and requiring relatively

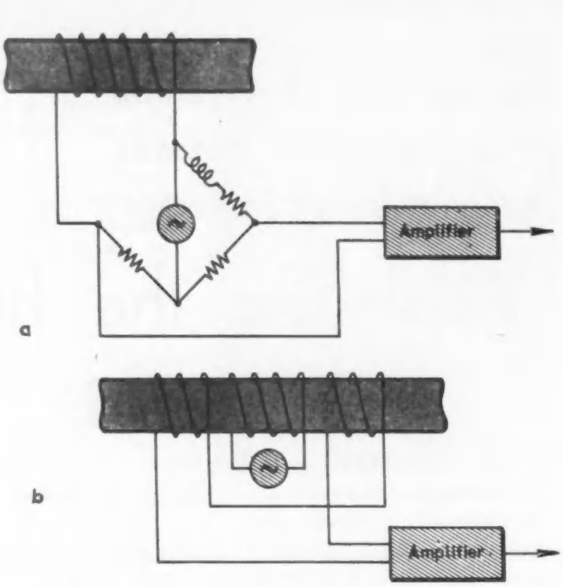


Fig. 14 Eddy current testing of a round bar. **a** The crack distorts the field and affects the impedance of the coil. **b** Two balanced detector coils. A crack under one of them unbalances the circuit and a voltage is fed to the amplifier

simple equipment; coupling between the coil and the work is not usually critically dependent on the spacing between them, and physical contact with the work, which may be moving at high speed, is not necessary.

WEIGHING

For automatic weighing the indication must generally be converted to an electrical signal; if the result is to be printed, as is common, then the signal must be in digital form.

The most common type of weighing machine is the conventional dial-type scale. In these the rotation of the pointer spindle must be converted into a digital signal in electrical form, and any device which is attached to the spindle must not apply a load to it sufficient to significantly affect the accuracy. A number of methods have been used but none have been used widely enough to have been generally accepted as being fully proved in practice. One popular method is to convert the spindle rotation to an analogue voltage by means of a low torque potentiometer or a synchro; the analogue signal is amplified and converted to digital form at a point remote from the weighing machine.

Modern load cells of the resistance strain gauge type are claimed to be capable of an accuracy of 0·1% of maximum load. The output from these cells is in the form of an electrical voltage and they are thus very suitable for automatic weighing.

A third method of weighing which is being developed for rapid checking of small parts and packages uses the force balance principle. The device consists of a balance arm with a position detector for measuring its deflexion and an electromagnet arranged to apply a moment proportional to current. When the load is applied to the balance arm, the amplified output of the detector controls

the magnet current in such a way that the arm does not deflect. The current in the magnet coil is then proportional to the load.

FUNCTIONAL TESTING

This kind of test is a common form of final inspection of an assembly. The checking of the performance usually involves a number of visual and aural observations and the operation of the controls of the device. Little progress has been made so far in making such tests automatically, mainly owing to the complexity and subjective nature of the checks involved. A notable exception to this is in the automatic manufacture of electronic circuits. In this manufacturing technique components are mounted and soldered to printed circuit boards in hopper fed machines and the circuits are then checked for correct connexions, insulation and continuity automatically.

FUTURE DEVELOPMENTS

The use of automatic inspection methods with their advantages of speed and consistency is at present in many parts of industry still in the stage of pilot production experiments. As experience is gained by the users the demand for this type of equipment will expand greatly. Dimensional gauging 'on the run' is a field in which a technical 'break through' has been achieved in recent years, and a great increase in this form of inspection is foreseen.

Another field in which increasing use of automatic methods is expected is in flaw detection. In the past the high cost of this kind of inspection has confined it to materials and components in which the manufacturing cost is itself high. In the future we can expect to see the extensive use of automatic flaw detection equipment for the inspection in bulk of intrinsically cheap material such as steel sections.

Techniques

Technical developments are no less important than the growing need for available equipment. While we may expect continued progress in the design and application of equipment based on existing knowledge, industry also needs further developments in the basic techniques.

In the field of flaw detection the problem of determining the size of flaws remains without any general solution and it is doubtful whether ultrasonic and eddy current methods will ever give an entirely satisfactory answer. It may be that we shall have to turn to gamma- and X-rays and devise automatic methods which will match the examination of radiographs by the human eye.

To be able to determine the size and nature of a flaw would be a great step forward but its potential value will only be realized fully if the effect of flaws of various types and sizes is properly understood. The cost of perfection in engineering materials would be prohibitive; the future need will be for rationally based specifications concerning acceptable flaws and reliable economic methods of measuring them. With this knowledge and equipment, it may well be possible to reduce the cost of materials because lower grade material, if properly specified and tested, may be acceptable for many purposes.

Fig. 15 Current density distribution in a round bar inside a long concentric coil

The difficulties of surface examination for local faults have already been mentioned. Here again there is scope for a new approach to the problem.

Finally the techniques available for automatic checking of the bulk characteristics of material (alloy composition, impurity content, heat treatment, etc) leave much scope for improvement. The weakness of almost all the available methods is that the results are affected by a number of variables of which only one is to be measured. Here more information about the relationships between the parameters concerned is needed or, better still, new methods must be devised. As in the case of flaw detection, it may be that methods which are at present only practicable for relatively slow manual operation must be adapted. For example, in the case of alloy composition and impurity checking, spectrographic methods provide the discrimination and independence of other factors required, but as quantitative automatic instruments they are today elaborate laboratory instruments requiring prepared samples.

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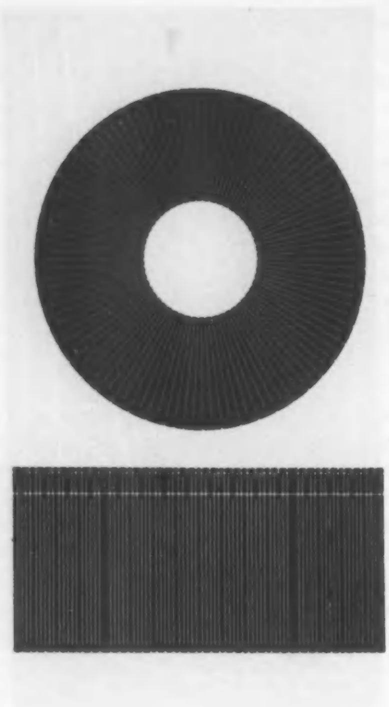
ELECTRICAL TRANSDUCERS—6



Digital v analogue is a fashionable controversy in many control engineering applications. If at heart you are an analogue man and digital ideas mystify you, read this admirably clear article

DIGITAL TECHNIQUES

by **R. E. FISCHBACHER,** B.SC., A.R.T.C., A.M.I.E.E.
British Scientific Instrument Research Association

THE ESSENTIAL DIFFERENCE BETWEEN ANALOGUE AND digital instruments lies in the number of values which can be assumed by the output. In an analogue instrument the output bears a simple relation (usually that of direct proportionality) to the input. If the input is continuously variable the output can in theory assume an infinity of values. A homely example of analogue presentation is the figureless clock. The digital device, however, is limited in the number of values which its output can indicate. Suppose, for example, that a digital indicator is equipped with one decimal digit register, then it can

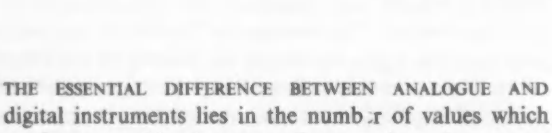


Fig. 1 A train of pulses signifying a binary number

assume any one of ten states corresponding to integers from 0 to 9. If such a register were fed from a voltage source, variable from 0 to 9 V, an input voltage of 6·5 V would read either '6' or '7' on the register, a possible error of 5% of the full-scale reading. Accuracy can, of course, be improved by adding additional digits until the required accuracy is reached, but the number of output states available will always remain finite. An everyday example of digital presentation is the odometer (i.e. distance recorder) of a car.

Analogue, digital: pros and cons

What are the advantages and disadvantages of analogue and digital systems? The answer is that it depends on what use is to be made of the information. For human appreciation and use digital information is essential, but long practice in reading clocks, rulers, meters and a host of other analogue devices has made man, and particularly technical man, a versatile analogue-digital converter. A fleeting glimpse of a distant clock face will suffice to determine the time with an accuracy adequate for most purposes. Possibly this highly developed facility will prevent the digital clock, which has already made its appearance, from becoming more than a novelty.

Where a large number of observations have to be made by unskilled or semi-skilled personnel, as, for

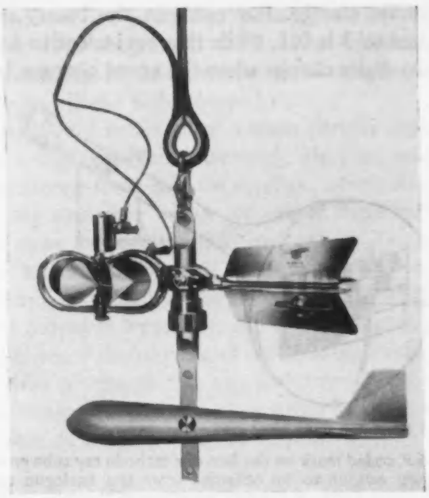


Fig. 2 This turbine flowmeter has a contact pick-up operated by the vaneshaft, which gives a pulsed output

example, during routine inspection or testing during manufacture, a digitized display has obvious advantages in eliminating reading errors.

Information can be stored in either analogue or digital form. In analogue form as a graph on a recorder strip chart it lends itself to rapid appreciation of trends or of cyclic variation. Digital storage as a tabulation of numerical values may be more useful when questions of accuracy or tolerance limits have to be decided. Apart from the visible methods of storage described, both kinds of information can be stored electrically or magnetically, for example, on a magnetic tape or drum as a continuously varying signal (analogue) or as a series of pulses (digital).

Processing of information can in turn be carried out by either analogue or digital computers. Analogue computers are in general simpler than digital computers, but their accuracy is limited by the accuracy with which their electrical characteristics can be maintained, normally to about $\pm 1\%$ (although $\pm 0{\cdot}1\%$ can be achieved) and accuracy is progressively lost as further computations are carried out. The computation process

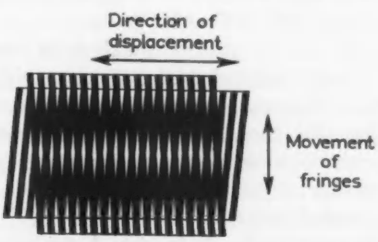


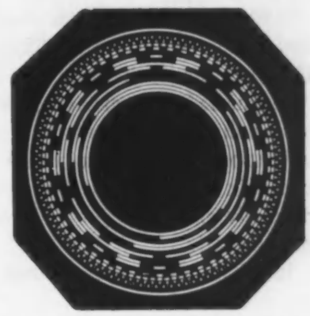
Fig. 3 A moiré fringe pattern produced by two similar inclined diffraction gratings

is essentially a continuous one. In the digital computer, accuracy is theoretically limited only by the number of digits employed, though in practice a limit will be set by the accuracy of the data to be processed. Since the digital system is essentially a discrete one, processing of information by digital computer is discontinuous and is based on sampled data.

In process control, instrumentation has to perform a number of functions. Information about the performance of the system has to be extracted, processed and used to control plant operation. At the same time it is usually required to log some of the information, preferably in digital form as a tabulation of figures for future reference or check computation. This is leading to greater emphasis on the need for instruments with digital output.

Most physical processes are continuous rather than discrete. It is not surprising, therefore, that transducers normally yield an analogue output, although a few produce digital results directly. To enable those with analogue output to be used in digital systems, analogue/digital conversion is necessary. In considering digital

Fig. 4 Pick-off from this typical digitizing disk may be obtained electromechanically or photoelectrically



techniques in instrumentation we may conveniently distinguish two types of device: the digital instrument, and the analogue/digital converter. In addition, digital display and counting techniques are of considerable importance. However, before considering these devices themselves, brief consideration of the numerical notations used is desirable.

Binary notation

By education and custom we think normally in terms of the decimal system. That is to say, by the use of a single digit we can distinguish ten quantities 0, 1, 2 . . . 9. Quantities greater than ten require the use of two or more digits, the additional digits having progressively greater significance. For example, the 5 digit number 56723 signifies:—

$$5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

As digits move to the left they increase in significance by ascending powers of 10.

Any base other than 10 can be used, but the only one which interests us here is the base 2. Only two quantities can be distinguished by the use of a single digit. These are usually designated 0 and 1. The binary equivalents of the first few decimal numbers are:

Decimal	*Binary*
0	0
1	1
2	10
3	11
4	100
5	101

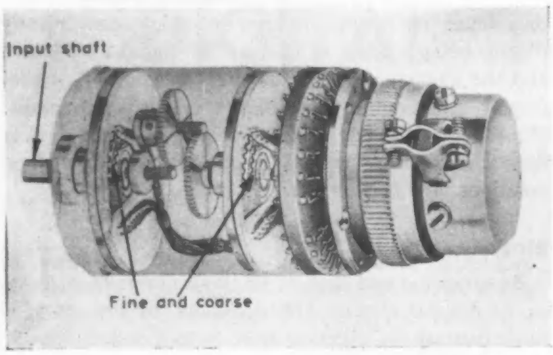
The significance of the binary number 11101 is now

$$1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$
$$= 16 + 8 + 4 + 0 + 1 = 29$$

To appreciate the usefulness of the binary system, consider a situation in which we wish to transmit information which takes the form of a number between 0 and 999. If we do this over three lines—one for each of the digits—then ten states must be distinguishable in each line in order to indicate the appropriate digit. The ten states may be ten voltage levels. However, the tolerances in electronic devices and the vagaries of transmission lines make it likely that confusion between two voltages initially only 10% different may occur. Large errors may be introduced if this confusion occurs in the most significant digit.

With the binary system more lines are required; 10 binary lines will serve to distinguish $2^{10} = 1024$ states. However, on each line, only two states have to be distinguished—for example, the presence or absence of a voltage or current. It is the unambiguity of the indication on any line which commends the binary system in digital circuits. Two-state devices or circuits are relatively simple to produce electrically, optically and mechanically.

In the example given the digits appear simultaneously



courtesy Plessey Co

Fig. 5 A multi-turn electromechanical digitizer

on a number of lines, which is ideal for presentation purposes, and this is often called a 'parallel' digital system. Sometimes, however, the digital output is presented on a single line as a time sequence of pulses, as in Fig. 1. This is known as a 'series' or 'serial' system. The presence of a pulse in a given position indicates the digit 1, while its absence indicates 0. The pulse train shown represents the binary number 110101. The train of pulses is usually preceded by an identifying pulse or series of code pulses which are used to indicate when the significant pulse train commences. This is vital if the first digit is 0.

The simple binary notation is rarely used in practice; various binary 'codes' are used instead. The reason for this is that in many analogue/digital converters it is desirable that, when the count changes by one, only one digit should change. For example, the binary number equivalent to 3 is 011, while that equivalent to 4 is 100. All three digits change when the count changes by one.

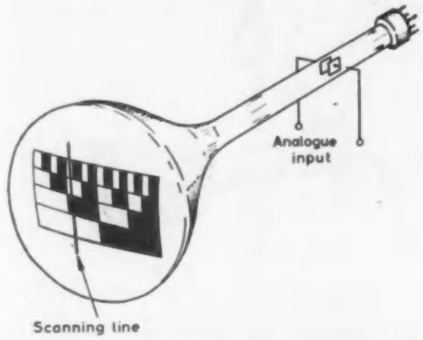


Fig. 6 A coded mask on the face of a cathode ray tube enables a digital output to be obtained from the analogue signal applied to the deflecting plates of the tube

In the Gray code, the reflected-decimal code, and others, only one digit transition takes place per count.

Examples of digital instruments

The simplest type of digital instrument that can be visualized is the cyclometer or odometer, in which revolutions or part revolutions of a shaft operate a digital display directly. Equally one may regard it as an analogue/digital converter where the shaft position is the analogue input, and this indicates the slight artificiality of the classification of digital devices.

The turbine flowmeter is frequently provided with a digital output. A capacitance pick-up senses the capacitance change as each vane passes, and produces a pulse which can be made to operate a counter. Total flow is proportional to the number of pulses. Where flow rate, rather than flow, is concerned, pulse frequency is commonly used, and this is, of course, an analogue quantity. However, if the instrument is arranged to count the number of pulses in a given time the output is digital. Fig. 2 shows another type of turbine flowmeter.

The moiré fringe displacement measuring device of Fig. 3 can also be used as a digital transducer. Two similar transparent diffraction gratings are superimposed with their rulings slightly inclined to one another. Alternate light and dark fringes appear at right angles to the rulings. Relative displacement of the gratings by one ruling pitch displaces the fringes by one fringe in a direction at right angles to the grating displacement. Detection and counting of the fringes by light beam and photocell yields a digital indication of displacement.

An electromagnetic device which operates in a very similar manner is the linear Inductosyn (see CONTROL, February 1959, p 76). Two fine grids of wire, one of which is fed with an alternating current, are close to each other. Relative movement of the two grids results in variation of the output from the second grid. As an analogue device it is capable of very high resolution: as a digital device it can be made to give two counts for

displacement of one grid pitch, and is therefore relatively insensitive. (The diagram at the head of the article on p 68 gives an idea of the elements—metal on glass—used in rotary and linear Inductosyns.)

Devices for the detection of nuclear particle radiation fall into a slightly different category. Here the stimulus exists in discrete form, and the detector, which may be a scintillating phosphor or an ionization chamber, produces a pulse for each particle intercepted. The pulses can then be directly counted.

As already indicated, other transducers, in which the analogue output is frequency, can be regarded as being digital devices if the number of cycles is counted over a given period of time. In this way such transducers as the acoustic strain gauge or vibrating string barometer may be regarded as yielding a digital output.

Analogue/digital converters are widely used

The preponderance of analogue transducers renders it necessary to interpose a translating unit between the analogue transducer and the succeeding digital equipment. This is the role of the analogue/digital converter or digitizer. The term 'quantizer' is sometimes used since the digitizer output represents the analogue input in

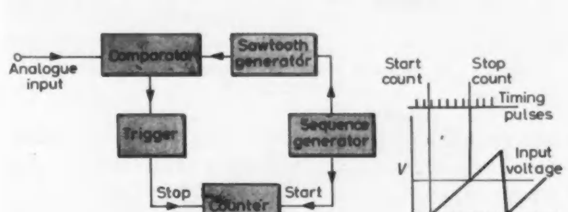


Fig. 7 Schematic of a simple electronic digitizer and an explanation of its voltage/time operation

multiples of a basic 'quantum', which is the value of the least significant digit.

Two types of digitizer will be distinguished. The first has a mechanical input, usually a shaft position: the second has electrical input, usually voltage.

Mechanical-input digitizers

The simplest digitizer of the mechanical type is the odometer. The analogue input is in terms of turns of a shaft and the digits are usually presented in decimal form. By suitably gearing this type of counter fractions of a revolution can be indicated. For high resolutions, however, a high gear ratio would be required, and backlash and torque problems are considerable.

The more usual form of shaft position digitizer has a coded disk mounted on the shaft. This disk bears the digital information. A typical disk is shown in Fig. 4. The pick-off from the disk may be electromechanical or photoelectric. In the former the segments are alternately conducting or non-conducting, and a wiper in contact with the face of the disk determines the condition of the segment with which it is in contact. A separate wiper is used for each annular ring of digits. With photoelectric pick-off the disk segments are alternately opaque and translucent. A light source illuminates a radial slit, and a separate photosensitive detector for each digital annulus is either illuminated or dark.

Here can be seen the reason mentioned earlier for the coding systems adopted. In a perfect instrument in transition from position 3 (binary 011) to position 4 (binary 100) all three binary digits should change at the same instant. However, in practice one of the contacts

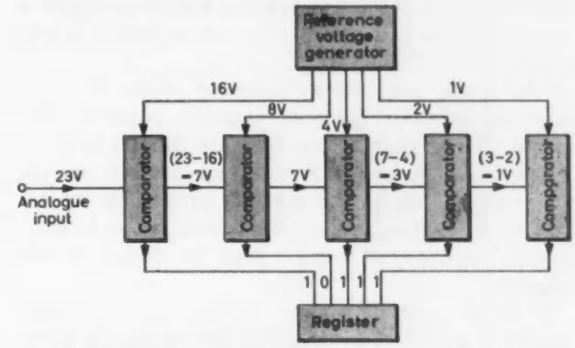


Fig. 8 Feedback encoding is used in this electronic digitizer where difference voltages are sequentially compared with standard voltages representing powers of 2, as used in the binary system

or photodetectors will inevitably change before the others and should the disk come to rest when this has just occurred, a false indication will result. For example, should the first digit be first to change, the digitizer will read 111, equivalent to the decimal 7, instead of 4. Codes are designed to ensure that this cannot happen and that any inaccuracy of alignment of pick-offs cannot result in an error of more than one least significant digit.

A less favoured alternative to coding is the use of two brushes or contacts per digit, one leading the other. The transition of the least significant digit controls the change from lagging to leading brush on more significant digits, thus ensuring that effectively all transitions are simultaneously made.

However, it is not always required to convert to pure binary digits. Decimal digitizers are advantageous where direct decimal presentation is required. These converters usually first divide the complete rotation into decimal parts and then quantize each of these in binary terms. Four binary digits offer 16 combinations of which only ten need be used for each decimal digit. Each decimal digit has now to be decoded. This is a relatively simple operation. By associating one relay with each digit—i.e. four relays per decimal digit—the translation is readily accomplished. Similar techniques are used for decoding from pure binary codes to decimal form but the decoding equipment required is somewhat more complex.

Resolution and torque

The resolution of coded disk digitizers is a function of the diameter of the disk, and also of the pick-off system.

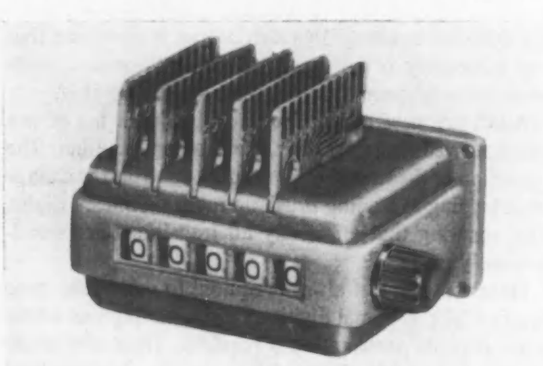
Photoelectric pick-off is more accurate than electromechanical. An optical disk digitizer of 2¼ in. diameter can resolve 1 part in 1000 of a single turn. A disk of similar diameter with electromechanical pick-off is unlikely to resolve to better than 1 part in 500, and more usually to 1 part in 250. Much better resolution is often obtained by gearing the digitizer so that the disk makes many turns for every turn of the input shaft. The digitizer shown in Fig. 5 can resolve 1 part in 524,288 over 4096 turns of the input shaft. The gears are enclosed in the instrument with a separate coding disk which counts the turns of the fine resolving disk. This resolution is achieved in a diameter of 1¾ in. and an overall length of 5¾ in.

The torque required by digitizers varies with the instrument, optical pick-off naturally requiring less torque. The torque may vary from less than 0·1 oz-in. to a few oz-in. Readings may be taken from moving digitizers by pulsing the read-out system. In optical devices the light source may be flashed and in electromechanical digitizers a pulse may be applied to the contacts.

A further type of optical digitizer uses a circular version of the moiré fringe diffraction grating. By using fine gratings and by counting the passage of fringes at several points over one fringe pitch, high resolution can be achieved.

Electrical-input digitizers

Where the analogue output of a transducer cannot conveniently be presented as a shaft rotation but appears as an electrical signal, or where high-speed operation is essential, electronic techniques have to be employed.



courtesy Veeder-Root

Fig. 9 This electromechanical counter has provision for electrical read-out

A simple high-speed equivalent of the optical disk digitizer is shown in Fig. 6. The analogue signal deflects a vertical trace on the face of the cathode ray tube across a coded mask, and the output is read photoelectrically.

A purely electronic digitizer is shown schematically in Fig. 7. A voltage generated by the instrument rises linearly with time, linearity being consonant with the accuracy of the digitizer. This voltage is compared with the input voltage, and when the comparator senses equality it produces a triggering signal. The instrument also produces a series of timing pulses. At the instant at which the sawtooth voltage begins to rise, the counter starts counting timing pulses. When the two voltages are equal, the counter is stopped by the triggering pulse. The number of pulses counted is proportional to the voltage input.

Another system, sometimes known as 'feedback encoding', is illustrated in Fig. 8. A succession of comparisons is made between the input voltage and reference voltages, each reference voltage being half the preceding one. For example, a system with a range of 32 V and resolution of 1 V, receives an input of 23 V. In the first comparison the input is compared with 16 V. Since the input is greater, the comparator registers one binary digit, and passes on the difference voltage of 7 V to the second comparator which compares this with 8 V and registers no digit, but passes 7 V to the third comparator. Comparison with 4 V registers one digit, subtracts 4 V and passes the residual 3 V to the last two comparators, which register in turn one digit each. The binary digitized output of the converter is therefore 10111.

courtesy Rank Cintel

Fig. 10 An electronic counter displaying decimal digits on electric meters

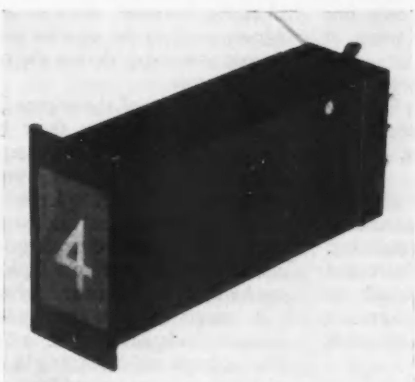
In both these forms of electronic digitizer, the accuracy of the comparators sets a limit to the accuracy of quantization. High accuracy is therefore only achieved with high voltages at the comparators. Rate of operation is dependent on accuracy of digitization since higher accuracy implies the determination of additional digits. Speeds up to about 100,000 per second are claimed.

Counters

Counters are an essential feature of digital techniques for registering the number of pulses from, for example, the turbine flowmeter or the timing pulses in the sawtooth type of digitizer. The counter may count in the binary system or the decimal system, and it may present its output in electrical form only or visually. The simple electromagnetic counter of Fig. 9 gives a visual decimal count together with decimal read-out from switch contacts. It will count up to 1000 per minute.

High-speed counting must be done electronically. For speeds up to about 20 kc/s binary or decimal counting can be carried out by cold-cathode binary or decade selector valves. In these valves a gas discharge is established between an anode and one of a number of cathodes. Application of a pulse of specified characteristics causes commutation of the discharge from one cathode to the next, and so on round the ring of cathodes. When the discharge has commutated right round the ring it returns to the initial, or 'zero', cathode. The current flowing in the 'zero' cathode produces a pulse in a cathode load, and this pulse can be passed on to the next counter tube, which will receive one pulse for each ten pulses received by the first.

Where speeds above 20 kc/s are involved valve or transistor counters must be used. These employ bistable circuits or binaries which reset on every second pulse. Decimal counters are composed of four binaries in which feedback advances the count by four and then by two, so that after the receipt of ten input pulses, the register behaves as if it has received its full quota of 16 pulses. Very high speed counters usually employ valve or transistor circuits for the first few stages, the later stages being cold-cathode counter tubes. Speeds up to about 10 Mc/s have been achieved, and counters with speeds up to 1 Mc/s are commonly available. Most high-speed counters are associated with accurate timing facilities so



courtesy Hilger & Watts

Fig. 11 A typical in-line display, comprising a stack of ten Perspex plates engraved with numerals and illuminated from the edge

that count rate or frequency can be determined. A typical high-speed counter-timer is shown in Fig. 10.

Digital presentation

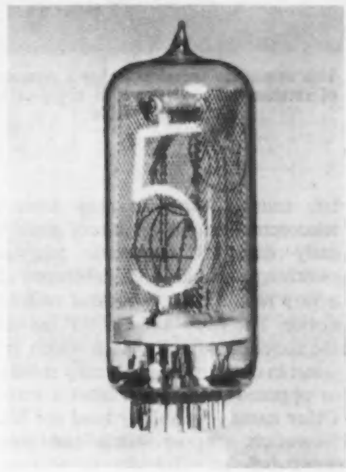
The presentation of digital information is a problem to which no final satisfactory solution appears to have been found.

Where counting rates are low, the mechanical or electromechanical type of indication as in Fig. 9 is satisfactory. Another simple indicator, used in the equipment of Fig. 10, consists of a meter calibrated with the numerals 0–9 and fed with one of ten discrete currents or voltages to deflect the pointer to the appropriate indication. In most applications, however, speeds are much too high for this simple solution, and where already accumulated counts have to be displayed a near-instantaneous display is often required.

The simplest solution is to utilize the glow of the cathode discharge in the counter tube. The cathode ring is arrayed round the top of the tube, which is mounted horizontally with the end projecting through the front

Fig. 12 A Digitron digital display tube containing ten wire cathodes in the shape of numerals superimposed on each other

courtesy Ericsson Telephones



panel of the instrument. A numbered escutcheon surrounds the tube head and the glow position indicates the appropriate digit.

Optical digital presentations in which numerals are illuminated as required assume various forms. In the simplest, a vertical line of ten digits, each with its own lamp behind, permits the illumination of any individual digit. It has the disadvantage that it involves a spatial dispersion of the numerals which makes it hard to read.

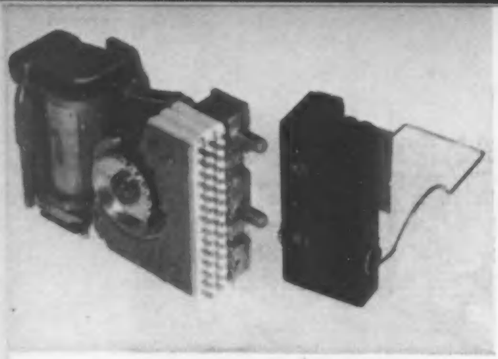
A subtler application of the same technique, which also permits 'in line' presentation of successive digits, is to superimpose a set of ten transparent plastic plates each with its own numeral. By edge-lighting the plates individually any one numeral can be made visible (Fig. 11).

This device has the advantage of being slow in operation, and other devices, based on gas discharge, have been used. One such arrangement is found in the Digitron, shown in Fig. 12. This is a gas discharge tube in which are a number of superimposed wire cathodes, each in the form of a numeral. When the appropriate cathode is energized, the numeral glows brightly. The wires of the remaining cathodes are sufficiently thin not to be noticeable.

A further method deserves mention. Numerals can be synthesized on the face of a cathode ray tube after the well-known Lissajous figure technique. The numerals 0, 1, and 8 can be produced very simply with harmonically related sine waves. A few additional elements for phase changing and rectification enable the whole range of numerals to be produced in any required size or position on the cathode ray tube face.

Correction to last month's issue

On p 100 of last month's issue the acknowledgments for the photographs were not stated correctly. In fact Fig. 5 was reproduced by courtesy of Firth Cleveland Instruments and the photograph at the head of the article by courtesy of Foxboro-Yoxall. We apologize to these two firms for the mistake.



This miniature uniselector has a new type of ratchet-and-pawl drive, is compact and easily removable

CONTROL 9 SURVEY

UNISELECTORS

by G. F. MACHEN, B.Sc.(Eng.), A.M.I.E.E.

Post Office Engineering Department

THE UNISELECTOR HAS BEEN USED BY telecommunication engineers since the early days of automatic telephone switching and has been developed into a very reliable and economic switching device. The word 'uniselector' indicates the function of the device which is to select in one direction (actually rotation) as opposed to selection from a matrix. Other names commonly used are selector-switch, stepper-switch and rotary line-switch.

Uniselectors can be divided into two classes, those driven by a ratchet-and-pawl actuated by an electromagnet, and those driven by a small electric motor. Both types consist of three main sub-assemblies, the bank, the wiper assembly and the drive mechanism.

Banks and levels

The contacts from which the selection is to be made are arranged in a manner of arcs (usually half circles) all with their centres on a common axis. Each arc is called a level and the group of arcs is called a bank. The contacts are of 18% nickel silver (Ni, Cu, Zn) but can be plated with noble metal when required for low voltage applications, such as thermocouple scanning.

The number of contacts in a level and the number of levels in a bank will depend on the type of uniselector and its application.

Where homing-facilities are required, i.e. restoration to a predetermined position, ratchet-and-pawl driven uniselectors are provided additionally with a level consisting of a continuous arc extending over the space occupied by all but one contact, a single contact being provided for the home position. In some uniselectors two home positions are provided.

The wiper assembly

The moving contacts of a uniselector are called 'wipers' and are mounted on a spindle at the axis of the bank. They can be either single-ended or double-ended giving respectively one or two complete sweeps of the bank contacts per revolution when the bank levels are half-circles. Electrical connexion to the wipers is through brush feeds which are in continuous contact with the collector disks associated with each wiper. There are other arrangements such as where the contact levels extend over 120° and three wipers at 120° spacing are used.

Both the wipers and brush feeds are in pairs giving twin electrical connexions through the uniselector. Compared with single contacts this twinning reduces, by a large factor, the chances of high resistance contact occurring. The wiper tips can be bridging or non-bridging: the bridging wiper ensures continuous contact with the level as the wiper passes from contact to contact and the non-bridging wiper ensures that only one contact is connected to the wiper at any time.

The material used for the wipers, brush feeds and collector disks is of the same composition as that used for the bank contact and these items can be plated if required.

A numbered wheel which is attached to the wiper assembly indicates the contact on which the wipers are standing. The current carried by the wipers and bank contacts should not exceed 1A and it is recommended that they are not used to break current. Adequate spark quenches are essential.

The drive mechanism

Two methods of drive are employed being known as ratchet-and-pawl drive and motor drive. The first is used on a wide variety of uniselectors and is usually of the reverse action type and rarely of the forward drive type. When the word uniselector is used without qualification it is the reverse type of drive that is being referred to. The second method of drive is used in the motor drive uniselector, which incidentally is the largest available having a maximum total of contacts in the bank of 816, made up of 16 levels each of 51 contacts.

Ratchet-and-pawl drive. The wiper assembly is coupled to a ratchet wheel which is driven by a pawl on the free end of a pivoted armature of an electromagnet. Energization of the coil by direct current moves the armature and the pawl drops over one tooth of the ratchet, the wipers remaining stationary on their contacts. Upon cessation of the current the armature releases under the action of a restoring spring and the wipers are moved to the next contacts. A typical minimum energization period for this movement to occur reliably is 30 msec with a release time in the order of 5 msec, and the break period of the non-bridging wipers is about 1 msec. This is the most usual type of drive and is called 'reverse' drive because the wipers move as the armature releases. This method of drive is more efficient than the 'forward' drive in which the wipers move in the operate period and remain stationary during the release of the armature.

The rotation of the wipers is always in the same direction there being no means of reversing them except in the cases of (a) the both-way uniselector which has a symmetrical ratchet tooth and two electromagnet and pawl assemblies, one for each direction of travel; and (b) the minor switch. Both of these mechanisms have forward drive.

A range of coils is available for operating voltages from 22 to 220 V d.c. The coils are self-protecting in the sense that if they are energized for a considerable period they will not dangerously overheat but of course the resistance increases considerably and subsequently failure to function may occur. It is recommended that wherever possible the energization time should be less than half the disconnexion time and not more than 5 sec.

Motor drive. This type of drive consists of a pulse motor whose rotor rotates smoothly at approximately 3000 rev/min and drives the wiper assembly by a train of gears, the wipers rotating at approximately 120 rev/min. The rotor is made of magnetic iron, has no windings and is of low inertia so as to reach normal running speed very rapidly; when stopping the deceleration is high. While in motion the wipers rotate smoothly and are not stopped on each contact in turn as in the ratchet drive;

instead, when the contact being searched for is reached the wiper system is locked in that position. It is important that this locking is controlled by a correctly designed circuit using the high-speed relay developed for the purpose as the wipers sweep over a contact in 5 msec and only a small proportion of this time is available for the relay to function. The operating voltage for this mechanism is 50 V, each of the two motor coils having a resistance of 45 ohms and the locking device having a coil of 100 ohms.

A correct control circuit is essential

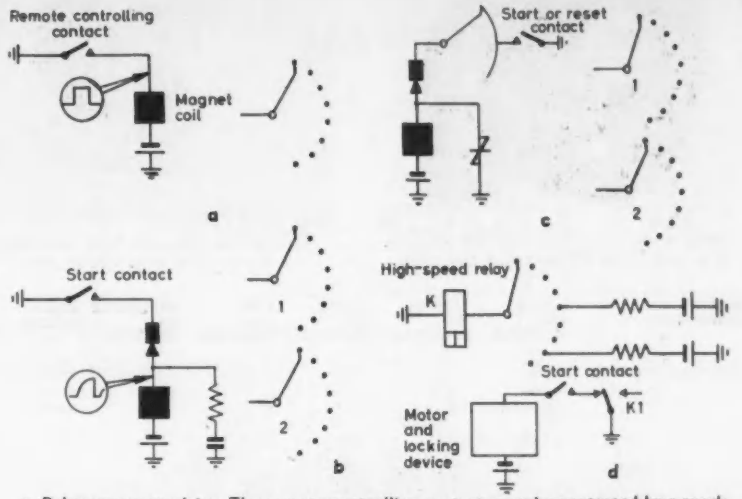
For the reliable functioning of these mechanisms it is essential that the control circuits be those recommended by the manufacturer. This particularly applies to the motor drive uniselector as its speed of operation (number of contacts swept/sec) is three times as great as the average ratchet-and-pawl drive type. The power must be cut and the locking device actuated with the wipers in exactly the right position so that the lock is effective and the wipers are finally positioned on the correct contact.

The circuits for ratchet drive

As previously stated there are two methods of operation, i.e., pulse drive and self-drive. Either of these, but usually the latter, can be applied via the contacts of a level of the same uniselector. By this means the mechanism can be made to search for a 'marked' position or 'homed' to a predetermined position.

Pulse drive. This is remote control drive in which square voltage pulses direct from a low impedance source are applied to the magnet of the uniselector by a remote contact. The pulse length should be at least 30 msec and the break between pulses at least 10 msec which gives a maximum speed of approximately 25 contacts/sec. Continuous pulsing without rest at this rate is not recommended. If a slower rate is sufficient the break period should be lengthened. It should be noted that the controlling contact will be damaged unless the correct spark quench is applied. A typical spark quench would consist of a resistance of 200 ohms in series with a capacitance of 1 μF as shown in **b** of the drawing on this page or a non-linear resistance as shown in **c** of the same drawing.

Self-drive (or self-cycling). The uniselector is fitted with interrupter contacts which are normally closed but which open when the armature has moved about half of its total travel. With this contact wired in series with the coil and a d.c. source the wipers will be driven round step by step at,



a. Pulse or remote drive. The remote controlling contact must be protected by a spark quench, preferably at the coil. Only one wiper (single-ended non-bridging) and one level have been given. It is conventional not to show the brush feeds and collector disks. **b.** Self-drive. A capacitance-resistance spark quench has been shown as an example. **c.** Homing. A non-linear resistance spark quench has been shown as an example. **d.** Motor drive

typically, 60 contacts/sec, equivalent to 75 rev/min. It is to be noted that at this rotational speed the wipers remain stationary on each contact for approximately 10 msec. The interrupter contacts will be damaged and the stepping will be erratic unless the correct spark quench is applied. Under these conditions although the energization time of the coil is greater than the off time the power required is about half of that absorbed under continuous energization of the coil without interruption.

The self-drive can be controlled by a high-speed relay dependent on a level of the uniselector as shown in **d** for the motor uniselector. By this means a marked outlet can be searched for at the self-drive speed. The high speed relay and its circuit should be designed so that it functions in less than 2·5 msec.

When it is required to return the wipers to a fixed home or normal position, usually contact 1, the mechanism is connected as for self-drive but in addition the homing arc and its associated wiper brush-feed are connected in series with the coil and interrupter. While the wiper remains on the continuous arc the mechanism drives the wipers but as soon as the connexion is broken the current to the coil ceases and the wipers take one more step. A non-bridging wiper is recommended for use in association with a homing arc. A normal level of contacts can of course be used as a homing arc by wiring all the contacts together except the home one(s). A bridging wiper must be used in this case.

The circuits for motor drive

The correct method of control of this uniselector is shown in **d**. One level of the uniselector is used to determine the position the wipers are to occupy. This position is 'marked' by the battery-connected resistor. When the start contact is closed the motor drives the wipers round the bank, the high-speed relay K remaining unoperated until the marked contact is found. When K operates the power to the motor is cut and the locking device is actuated. If more than one contact is marked the switch will stop at the first one it reaches. The nominal speed of this uniselector is 200 contacts/sec.

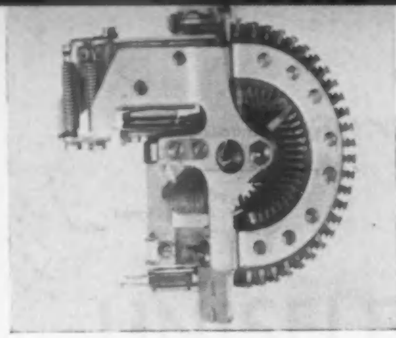
Mounting and life

All uniselectors create a certain amount of vibration. The motor uniselector creates only a small amount and is usually fixed directly to its support; the ratchet-and-pawl drive uniselectors however should be mounted on the special anti-vibration springs designed for them to ensure no transmission of the energy to other components. Whilst the mass of the non-moving parts of a uniselector is high, compared with the moving parts, the whole body does oscillate and for this reason components such as resistors and capacitors mounted on the uniselector must be fixed securely to it. The lead-out wires of the component are not strong enough for the purpose.

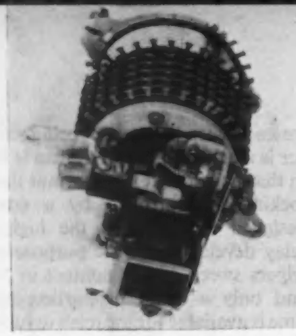
The length of time a uniselector will continue to function reliably depends on the method and frequency of use, its environment and the care with which it is maintained. The manufacturer should be consulted on this for any particular application. As a general guide a uniselector will last for around two million revolutions of the wiper assembly if the circuit in which it is used is well designed, its maintenance being kept to the economic minimum.

over ►

A large motor drive unit with 816 contacts. It is used in the PO for trunk switching



This ratchet-and-pawl drive uniselector is the type most widely used



The uniqueness of this miniature high-speed uniselector lies in its 360° bank

GENERAL DESCRIPTION	MOTOR UNI-SELECTOR	TYPE 2 UNI-SELECTOR	TYPE 2 UNI-SELECTOR	TYPE 3 UNI-SELECTOR	MINIATURE UNI-SELECTOR	MINOR SWITCH	12-POINT UNI-SELECTOR	HIGH-SPEED MINIATURE UNI-SELECTOR	BOTHWAY UNI-SELECTOR	DIGIT SWITCH
Maker and code	ATE motor uniselector SES 1300	ATE PO 2 ET N8184 GEC UN1100 SES 1800 STC 4150	ATE PO 2 ET N8187 GEC UN1300 SES 1800 STC 4150	ATE PO 3 ET N8190 GEC UN2100 SES 1950 STC 4130	SES 2250	ATE minor switch	ATE ATM 12-point uniselector	GEC UNI U4 series	GEC UN3301 or UN3341	SES uniselector 1703
Number of contacts per level	51	25	25	25	12	10	12	30	25	12
Number of levels per bank	8 or 16	up to 5	6, 8 or 10	up to 5	3	3	4, 5 or 6	3, 5, 7, 9 or 12	up to 6	8
Approximate angle of arc, °	180	180	180	180	120	90	120	360	180	90
Number of wiper arms per level	1 or 2	1 or 2	1 or 2 1 on 10 level	1 or 2	3	1	3	1	1 or 2	4
Type of drive (1)	Pulse motor	R & P reverse	R & P reverse	R & P reverse	R & P reverse	R & P forward	R & P forward	R & P reverse	R & P forward	R & P reverse
Rotational speed of wiper assembly (2), rev/min	100–140	60–100	50–100	70–100	85–120		55–90	100–200	65–90	62–87
Equivalent searching speed (3), contacts/sec	170–230	50–80	40–80	60–80	50–70	(9)	33–54	50–100	55–75	50–70
Approximate power (4), W	45	12	15	10	4		15	30	12	12
Range of nominal working voltage, V	50 only	22–220	22–220	22–60	22–50	12–50	12–60	24–110	12–220	50 only
Range of coil resistance available, ohm	2 motor coils each 45. Locking device 100	18–1750	18–1750		50–250	10+ parallel resistance of 80–175	6–150	11–150	9–1600	—
Coil resistance for 50 V working, ohm	as above	75	75	100	250	175	100	38	120	75
Minimum current to just operate (5), mA	Not applic-able	400	450	300	100	115	415	1000	250	400
Maximum current to not operate (5), mA		180	220	140	40	95	—	800	125	200
Minimum pulse length for reliable functioning at nominal voltage (6), msec		25	30	20	25	20	—	10	25	30
Approximate nett weight, oz	64 or 80	30	38	23	12	14	11	17	38	26
Overall dimensions (13)										
A in.	$8\frac{1}{8}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$2\frac{5}{16}$	$4\frac{1}{8}$	$3\frac{5}{8}$	3	$5\frac{1}{4}$	$2\frac{1}{4}$
B in.	3 or 5	$1\frac{13}{16}$	$2\frac{7}{8}$	$1\frac{3}{4}$	$1\frac{5}{16}$	$1\frac{7}{8}$	$1\frac{7}{8}$	4	$2\frac{1}{4}$	$4\frac{1}{8}$
C in.	8	$5\frac{5}{8}$	$5\frac{5}{8}$	$5\frac{5}{8}$	$3\frac{3}{4}$	$4\frac{1}{8}$	$4\frac{7}{16}$	3	$5\frac{5}{8}$	$3\frac{5}{8}$
Pitch of fixing screws, in.	$6\frac{13}{16} \times 2\frac{11}{16}$	$5\frac{7}{16}$	$5\frac{7}{16}$	$5\frac{7}{16}$	0·95	—	—	—	$5\frac{7}{16}$	$1\frac{5}{8}$
Usual vertical dimension	A or B	A	A	A	B or A	A	A	A or C	A	A
Notes	(7)					(10)	(11)	(12)		

1. R & P means ratchet-and-pawl drive.
2. The range is that to be expected from normal production. Fine adjustments to achieve a particular speed are not advised.
3. Searching speed is number of contacts of one level traversed by wiper in 1 sec. The range quoted is that to be expected from normal production. Fine adjustments to achieve a particular speed are not advised.
4. The power depends on the adjustment of the uniselector.
5. The current figures are for a nominal voltage of 50 V, and may be improved by adjustment of a particular sample.
6. A shorter time than those quoted, applicable to a nominal voltage of 50 V, may occur on a particular sample. When current sufficient to just operate is flowing the armature will take longer to operate.
7. Capacitance resistance spark quenching unit is essential and should be ordered with uniselector. A bank having 52 contacts per level is also available from SES Code 1400.
8. A special capacitance-resistance spark quench and clip is available for mounting on this uniselector and should be ordered with it.
9. Dimensions quoted include 42-point socket. Spark quench is supplied with mechanism.
10. Interrupter contacts are not fitted. A release magnet and return spring are fitted. The path through this switch is not by twin contacts.
11. A sequence switch is available on 3, 5 and 7 level banks.
12. The rotational speed of wiper assembly, the equivalent searching speed and the approximate power are for self-drive conditions.
13. The dimensions are explained with reference to a uniselector placed as shown in the illustration. A is the overall height; B is the overall width along the wiper axis; and C is the overall length.

ATE—Automatic Telephone and Electric Co
ET—Ericsson Telephones
GEC—The General Electric Co
SES—Siemens Edison Swan
STC—Standard Telephones and Cables

CHOOSING DAMPING RATIO FOR MINIMUM RESPONSE TIME

by **D. R. DUDGEON,** B.SC., A.M.I.E.E., A.F.R.AE.S.
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FREQUENTLY, THE DESIRED CHARACTERistics of system performance are readily interpreted in terms of the transient response. Although a linear system may be completely characterized by its response to any aperiodic signal it is usual to consider the step function response.

Most systems are required to reach a steady state as soon as possible after a disturbance. The time which a system takes to settle is clearly related to the largest significant time-constant in the response, which, for systems dominated by a quadratic mode, is $T = 1/\zeta\omega_n$, since the amplitude of the oscillation depends on the factor $e^{-\zeta\omega_n}$ for all realistic ($\zeta \leqslant 1$) conditions. This means that, for minimum response time, ζ should be as large as possible, and hence the critically damped system ($\zeta = 1$), achieves perfect correspondence more rapidly than a system with any other degree of damping.

In practice, the response time, or settling time, is defined as the time required for the oscillation of the response to decrease to less than a specified percentage of the final value. If such tolerance is acceptable, it will be seen from Fig. 1 that a slightly underdamped system can reduce the error in less time ($\omega_n t_2$) than the critically damped one ($\omega_n t_1$).

Provided that the resulting overshoot is not excessive and that noise limitations are satisfied ζ should be made as small as the response time specification will allow, since, by increasing the system bandwidth this reduction of ζ will enhance the ability of the system to follow more accurately any input demand.

Fig. 2 shows the time for the response of a second-order system to a step displacement input to settle within tolerances of 10% and 1% for values of ζ between 0 and 1, and (dotted) optimum response times for other tolerances.

The calculation has been made by taking the expression*

$$\frac{\theta_o}{\theta_i} = 1 - \frac{e^{-\zeta\omega_n t}}{(1 - \zeta^2)^{\frac{1}{2}}} \sin(\omega_d t + \phi)$$

and finding the value of $\omega_n t$ when the term $\frac{e^{-\omega_n t}}{(1 - \zeta^2)^{\frac{1}{2}}} \sin(\omega_d t + \phi)$ finally falls to a value less than the tolerance.

For convenience, the optimum values of ζ for given tolerances are tabulated with the associated response time $\omega_n t$.

Tolerance, %	1	2	3	4	5	7	10	15	20
Damping ratio ζ	0·82	0·80	0·75	0·72	0·69	0·63	0·59	0·52	0·46
Settling time $\omega_n t$	4	3·5	3·2	3·0	2·8	2·6	2·3	2·0	1·8

* $\omega_d = \omega_n(1 - \zeta^2)^{\frac{1}{2}}$; $\phi = \arctan[(1 - \zeta^2)^{\frac{1}{2}}/\zeta]$

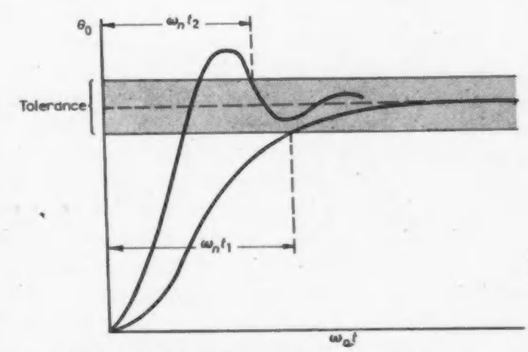

Fig. 1 Practical interpretation of response time

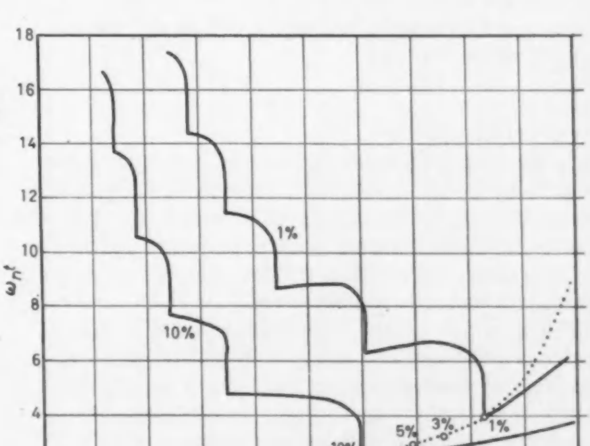

Fig. 2 Response time versus damping ratio for various percentage tolerances

MAKING AIRCRAFT SYSTEMS WORK

PART 2—CRYSTALLIZING THE DESIGN

Last month Foody and Mills discussed automatic control and design synthesis. Now they show how a system can be tested by using simulation

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A COMPLETE AUTOMATIC CONTROL SYSTEM WHICH MEETS the design requirements is not, as a rule, available. Normally, certain units of the system will be obtainable, but others must be designed from scratch. However, once a set of control equipment, some of it in breadboard form, is available, the next phase is to prove that the system does satisfy requirements for the aircraft under automatic control. Until recently, the only way to prove a system was to install the experimental equipment in an aircraft and carry out flight tests. This takes time, entails considerable modification of the original system and is, of course, extremely expensive. Dynamic simulation is, therefore, being used increasingly to reduce the amount of flight testing required.

Object of simulation

The aim of simulation is to produce a representation of the complete system in which all the individual units of control equipment operate as they would in flight. A large part of the design crystallization can be done in the laboratory before flight testing, and the system eventually installed in the aircraft will be much nearer to the final proven system. Perfect simulation of in-flight conditions is not possible, owing to the lack of complete knowledge of these conditions but, in our experience, the present state of the art enables valuable information to be obtained before any flying takes place.

To simulate flight conditions, the effect of some or all of the following variables must be represented:

1. Aircraft angular movements about the roll, pitch and yaw axes
2. Motion of the air surrounding the aircraft relative to the motion of the aircraft
3. Aircraft translational accelerations
4. Pitching, rolling and yawing moments about the aircraft axes, due to control surface deflexion
5. Engine thrust changes
6. Aerodynamic hinge moments on the control surfaces

To produce these effects, additional simulation equipment is used in conjunction with the actual control units themselves. The principal items are:

1. An analogue computer
2. A tilting table
3. A control surface loading rig
4. Coupling impedances

The analogue computer

The analogue computer, which is the nerve centre of any simulator, represents the motion of the aircraft relative to a set of arbitrary axes. The inputs to the computer are the displacements of the control surfaces and throttles, and the outputs are the resulting angular and translational displacements, rates and accelerations of the aircraft. The outputs are fed to the control equipment which senses aircraft movement in flight via simulation coupling equipment. The inputs are received from the simulated aircraft control so that, if the aircraft dynamics are correctly represented on the computer, the relationship between control and throttle movements and aircraft response will be as in flight. Fig. 14 shows a typical arrangement.

The aircraft equations from this set-up are adequate for investigating the stability of the aircraft alone, but when items of control equipment are being used in conjunction with the computer for simulation purposes,

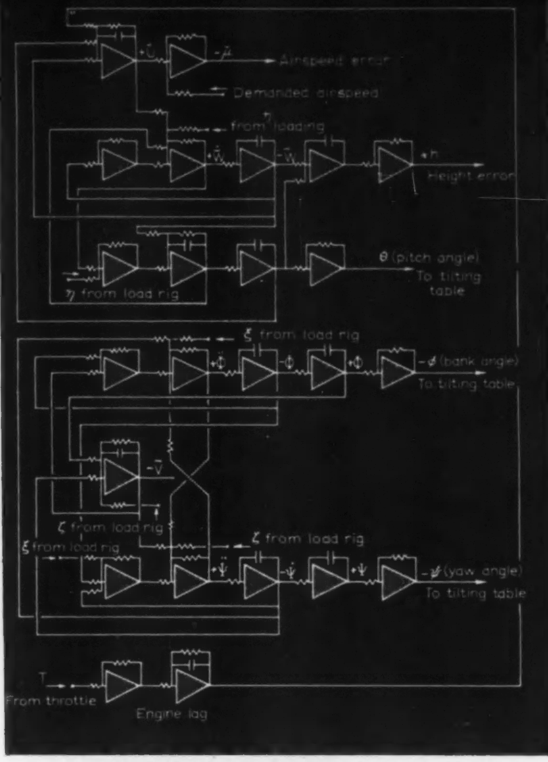


Fig. 14 Typical analogue computer set-up

certain precautions must be taken. To avoid distortions due to loading effects, the outputs from the computing amplifiers must feed into relatively high impedances, and the inputs to the computer be from relatively low impedance sources.

The computer must operate in real time because the remainder of the loop consists of control equipment operating as in flight. Furthermore, the period of the slow longitudinal aircraft mode can be several minutes, so that continuous operation of the computer for 15 or 20 min may be necessary. This means that drift in, say, a d.c. amplifier would be a serious source of error and some form of drift correction must be incorporated.

To achieve accuracy in the actual solution of the aircraft dynamic equations, the analogue set-up must be arranged so that the voltage levels in each equation are roughly equivalent. This is done by choosing suitable scaling factors between analogue machine voltage and aircraft parameter. It follows that to obtain the maximum computer accuracy, the scaling of the aircraft output variables will often be unsuitable for feeding to the next elements in the loop. Quite often, therefore, buffer amplifiers will be necessary to readjust the scaling of outputs or inputs before entry to the main problem set-up.

The gyro tilting table

Aircraft angular movements are detected in flight by the control system gyros, so the gyros must be subjected to similar movements in simulation. The computer output voltages representing these angular movements are at relatively low power levels; so a means of converting these voltage variations to angular motion is necessary. The gyro tilting table is used for this purpose.

The gyro tilting table, a typical example of which appears in Fig. 15, consists of a platform on which the gyros can be mounted, and which can be rotated about one, two or three axes. Hydraulic actuators are normally used and an amplifier system is necessary to raise the power level of the computer output. The actuators must be powerful since there must be negligible lag between input voltage to the table and output movement, and the frequency response should be flat up to several cycles per second.

The pitch, roll and yaw computer voltages are fed to the tilting table with the correct scaling factor, so that as the computer variables change, the table moves accordingly. The system gyros are then mounted and are subjected to movements similar to those of flight.

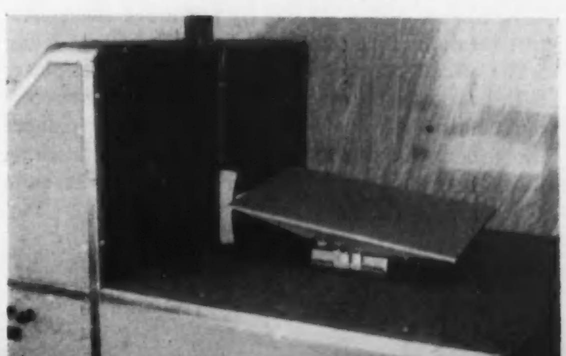
A tilting table for operation of the gyros may not be necessary always. For example, we simulated a simple system in which a rate gyro was used in the yaw channel. This gyro was of potentiometer pick-off type with pot magnet restraint, and possessed coils in addition to the feedback winding for monitoring etc. We fed the computer output to one of these monitoring coils via a resistor, which was used to increase the input impedance of the gyro, as seen from the computer output amplifier, and to adjust the scaling of the yaw rate signal.

Other sensing equipment

The remaining computer outputs—airspeed, fore and aft acceleration, height, and sometimes sideslip—must also be fed into the loop. In addition, if turning flight is to be represented, signals for turn coordination may be required. The same elaborate precautions with airspeed, acceleration and height are not as necessary as with angular movements, since these quantities vary slowly in flight and lags in the sensing equipment are of little importance. This permits the simulator engineer to gloss over the problem of producing air pressures which vary in accordance with the airspeed and height voltage outputs from the computer. Frequently, the height and airspeed capsules, and their associated transducers for producing the required autopilot signal, are by-passed and the respective computer signals fed to the output end of the transducers. If it is assumed that capsule and transducer lag is unimportant, allowance need only be made for the threshold, linearity and scale effects inherent in the sensing units. Tests can be carried out on the airspeed and height sensors themselves to determine the threshold input level, and the range of linear signal output per knot or per foot.

When first setting up the simulator, however, these

Fig. 15 Gyro tilting table for simulating flight characteristics



refinements may be omitted, as it is easier to add them to a system which is in operation. Inevitably there will be errors in setting up, or equipment faults in the initial stages, and less snag-shooting time will be involved if the system is kept as simple as possible.

To obtain a representative signal, the computer output can be fed to a further computer which represents the properties of the capsule and transducer, before finally feeding from the computer to the control equipment.

Forward acceleration is used as a control signal in some systems, but usually only as a means of obtaining an anticipatory speed signal for speed stabilization. In this case the acceleration term may be derived from an electrical phase advance network. If so, no difficulty is experienced in simulation, since the computer speed output can be fed into the equipment on the input side of the phase advance network.

Fig. 16 compares simulator representation and actual flying conditions, the sensing equipment receiving inputs such as those experienced in flight. The outputs of the sensing units are then directed to the amplifiers, as under

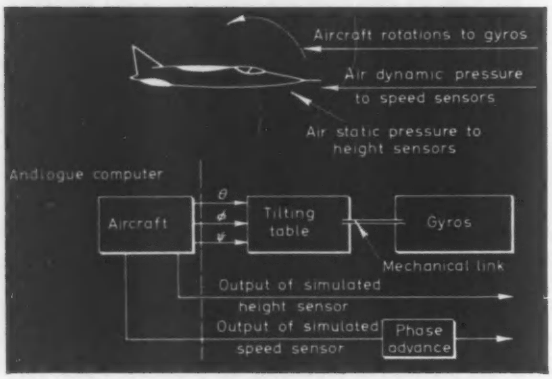


Fig. 16 A comparison of simulator and actual flying conditions

operating conditions, and are raised to a power level suitable for the operation of actuators via hydraulic control valves or, perhaps, electromagnetic clutches.

Control surface loading rig

In flight, the actuators operate the flying controls and throttles which provide the controlling moments and forces on the aircraft. On the simulator, it must be arranged that the control surface actuators move, against 'aerodynamic loads', and that their movement causes voltages representing control movement and thrust change to be fed back to the 'aircraft' set up on the computer. This is done with the loading rig.

The control surface loading rig provides a mechanical representation of the aerodynamic hinge moments acting on the aircraft control surfaces. In the normal power control example, the system is simple and can be represented adequately by an inertia, spring and damper arrangement. An even simpler representation, consisting of a linear spring on the actuator output, may be quite adequate.

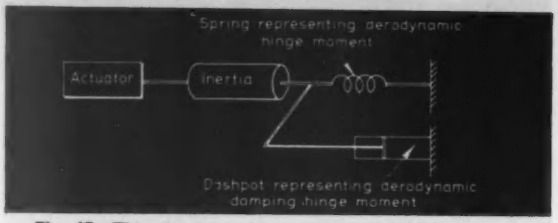


Fig. 17 This rig—inertial element, spring and damper—represents an 'aerodynamic and inertial load' on the actuators

In one particular simulation the control system was more complicated and incorporated a spring tab system. This introduced two degrees of freedom in the aerodynamic system (i.e. tab freedom and control surface freedom) but even here an equivalent system having a single degree of freedom and involving inertia damping and stiffness, was found adequate (Fig. 17).

In addition, a potentiometer is mounted on the rig frame and driven by the inertia so that displacements of the 'control surface' will produce voltages on the pick-off which can be fed back to the computer. The potentiometer should be of fairly low resistance to avoid electrical loading distortion, and the signal can be fed to the appropriate computer amplifier via a relatively high resistance, as shown in Fig. 18.

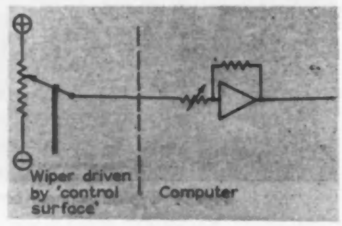


Fig. 18 'Control surface' displacement signals can be fed back to the computer via a potentiometer

The aircraft as a loading rig

Sometimes the aircraft itself can be used for control loading. The actuator is installed in the aircraft as for flight, and the controls are loaded with simulated stiffnesses and dampers. A Desyn, or some similar device, is used to measure the surface movement and transmit the required signal back to the computer. This method has the advantage that backlash and stiction are represented (admittedly in an unrepresentative aircraft condition) although these quantities will vary considerably from aircraft to aircraft. It may be necessary to carry out laboratory simulation first, modify the equipment to produce satisfactory behaviour under laboratory conditions, and then carry out the aircraft simulation. This is justified only if the aircraft control circuit has important properties which are difficult to simulate.

Throttle and engine representation

The throttle rig is comparatively simple for there are no aerodynamic loads, and our only concern is the inertia and friction of the linkage operating the engine controls. These do not vary with flight condition and it is possible to choose an actuator whose operation will be unaffected by the loading. Hence the rig may be simple and consist of an actuator-driven dummy throttle, which drives a potentiometer to provide the throttle-position voltage for feedback to the computer.

Before feeding this throttle-position signal to the

'aircraft', it is usually routed to a preliminary computer circuit representing the engines. Since thrust is most frequently used for speed control and sometimes for height control, and neither of these quantities varies rapidly, this circuit normally consists of a scaling factor and a simple time-constant. Engine response is sometimes more closely represented by a second, or even third, order transfer function but the time-constant (loosely, the time taken to attain 63% of the final thrust) is of the order of a few seconds, depending on the type of engine. The frequency of the height and speed oscillatory modes is much greater than this, so a first order transfer function is normally a satisfactory representation.

Simulator testing

The complete loop can now be set up. A typical loop diagram is shown in Fig. 19 and an actual experimental set-up in Fig. 20; the loading rig is in the foreground, and the computer and tilting table with the gyro equipment in the background. Such a simulation is a fairly complicated system, and care in preliminary testing and setting up pays dividends in time saved in locating errors or faults in the set-up. There are two reasons for preliminary testing: it provides information on the behaviour of the 'internals' of the complete loop; it establishes a test schedule which can be carried out each day before any results are taken, in order to ensure that the simulator is operating correctly. The loop is, therefore, broken at several points and open-loop tests are carried out.

For this purpose, it has been found convenient to subdivide the system as follows:

1. The computer set-up
2. Computer pitch output—pitch gyro output
3. Computer roll output—roll gyro output
4. Computer yaw output—yaw gyro output
5. Pitch gyro output—elevator actuator output

Fig. 19 Typical loop diagram—computer, tilt table, loading rig etc

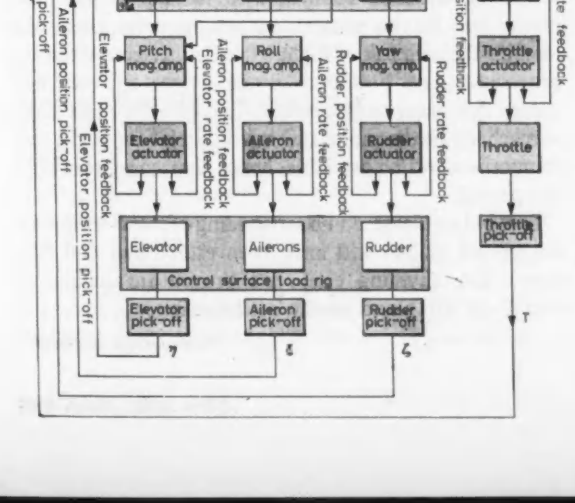


Fig. 20 Complete experimental loop. Note analogue computer and gyro tilting table in background, and the loading rig in the foreground

6. Roll gyro output—roll actuator output
7. Yaw gyro output—yaw actuator output
8. Pitch actuator output—elevator position potentiometer output
9. Roll actuator output—roll position potentiometer output
10. Yaw actuator output—yaw position potentiometer output
11. Computer height output—elevator/throttle actuator output
12. Computer speed output—elevator/throttle actuator output
13. Throttle actuator output—throttle position potentiometer output

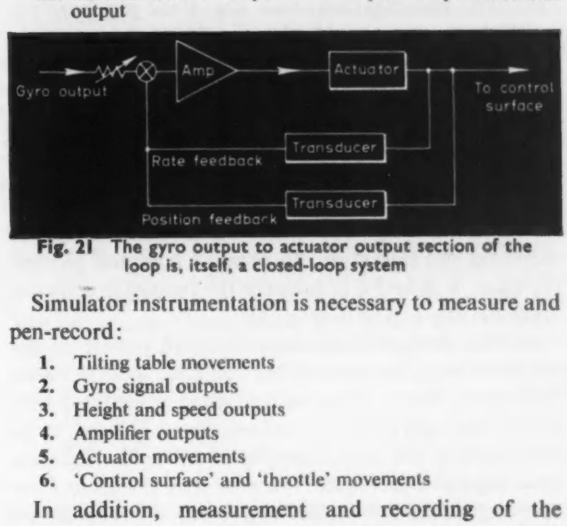


Fig. 21 The gyro output to actuator output section of the loop is, itself, a closed-loop system

Simulator instrumentation is necessary to measure and pen-record:

1. Tilting table movements
2. Gyro signal outputs
3. Height and speed outputs
4. Amplifier outputs
5. Actuator movements
6. 'Control surface' and 'throttle' movements

In addition, measurement and recording of the computer outputs are necessary, and the computer itself or its ancillary equipment will normally provide these.

The sections of the complete loop are then tested separately, first for functioning and sense, and then dynamically. The computer set-up can be checked by comparison with results obtained in earlier work, or if digital computing facilities are available by producing a digital solution of the equations.

Each section is then functioned by applying inputs, the results are observed qualitatively, and the relative sense of each output to its input is noted and any necessary reversals made. It is useful at this stage to measure threshold and saturation levels for each portion of the loop and to plot the static input-output relationship. This may assist in pin-pointing any discrepancy in overall open-loop sense or gain at a later stage.

It may happen that a section exhibits undesirable

characteristics on functioning qualitatively; the gyro output to actuator output section is a possible case in point, since this is itself a closed loop system. Fig. 21 is a typical simplified block diagram for this section.

This loop may be unstable, making it necessary to carry out a detailed analysis of its properties by breaking the feedback loops, and obtaining the open-loop frequency response of the amplifier-actuator combination. Suitable values for position and rate feedback gain can be found by standard servo techniques, provided that the amplifier and actuator are of sound design. In any event, undesirable properties will appear in this investigation and modification can be carried out. Normally the closed loop response can be varied over a wide stability range by altering the feedback gains; at this stage it is not often known whether critical damping or, say, 0·7 of critical damping is most suitable from the point of view of the overall response. Hence it is advisable to measure the frequency response at several sets of conditions for future reference.

Frequency response

Having established that each section of the loop functions correctly and that the static properties are satisfactory, one should plot the frequency response. Although the operating range of the equipment in flight is from almost zero up to about 2 or 3 c/s only, these measurements should be extended to higher frequencies to ensure that airframe or engine vibrations will be attenuated sufficiently. Since the system is non-linear, frequency response is also a function of input amplitude, the important amplitude values being related to system threshold and saturation. To obtain a complete picture, therefore, it is useful to measure the frequency response at several input levels in each case.

At this stage, a fairly comprehensive picture of the behaviour of all sections of the complete loop has been built up. Each section has been adjusted or modified until satisfactory operation is obtained, but it remains to be seen whether the interconnexion of all units will introduce any fresh problems. The next step, therefore, is to connect up the full system and break the loop at the output end (i.e. disconnect the links from 'control surfaces' and 'throttles' back to the computer). Complete system functioning checks are now carried out, first for sense and then for threshold and saturation. This can be done by applying inputs to the aircraft equations on the computer which represent external pitching, rolling or yawing moments, or external fore and aft, vertical or lateral, forces.

The frequency response of the open loop is determined by feeding sinusoidal inputs to the aircraft equations, and recording 'control surface' and 'throttle' output movements. Again, these measurements should be made at different input levels and for a range of values of system feedbacks constants, e.g. the ratio, elevator movement per degree pitch-attitude change. In general, the aim will be to use as high a forward loop gain as is consistent with stability, since this will reduce output-input errors. This is, of course, in line with general servo practice although several considerations in aircraft systems may make reduction of gain desirable.

Aircraft are subject to random inputs in the form of air gusts and, if the system gain is high, rough air conditions will lead to large correcting control movements which may apply excessive accelerations to the aircraft. This is particularly true of an aircraft control system which is used during the approach and landing phases, where irregular air conditions are very frequent and normal accelerations highly undesirable.

Moreover, the use of maximum gain needs careful consideration if the system is to control the aircraft during transition from one datum flight condition to another, rather than merely to stabilize it about a pilot-set condition. In a transition, a large error signal is fed to the system to initiate the change of datum, and this again would tend to call up excessive control surface movements. The resulting accelerations can be limited by deliberately introducing non-linearities: for example, the output torque of the actuators can be limited to a value which is not capable of producing violent changes on the aircraft. This, however, reduces the speed of response for large input errors, since the forward loop gain is effectively reduced. Obviously, therefore, the choice of a suitable gain is a matter for compromise.

The optimum values of feedback parameters can be specified from the measured frequency responses, normal servo-loop stability criteria and the special aircraft system requirements being taken into consideration. If the initial analysis of the system has been fairly representative, the main source of difficulty in obtaining stability will be non-linearity.

Structural vibrations

In many aircraft, the airframe will be subject to structural vibrations of relatively high frequency at certain airspeeds and Mach numbers. Any items of the control equipment which are rigidly attached to the structure must not cause these vibrations to be transmitted to the actuators or controls. Hence it is often useful to break the control loop at the points in question, and examine the frequency responses of the optimized loop up to and beyond the airframe frequencies.

To sum up: a great deal of dynamic and static testing can be done on the ground, simulation being used to check the dynamic characteristics of the system. No matter how far this process is taken, however, there still remains the acid test of flight trials. If the ground testing procedures have been carried out adequately, they will ensure that many snags are high-lighted before this stage is reached; furthermore, the raw material for flight test comparison will be available, hence shortening the flight test period.

Last but not least, an understanding of the workings of the overall system will have been established and this, more than anything else, has proved invaluable in trouble-shooting and system modification.

To be concluded next month

Producing teleprinter combination bars with a punched-tape-controlled rack-cutting machine

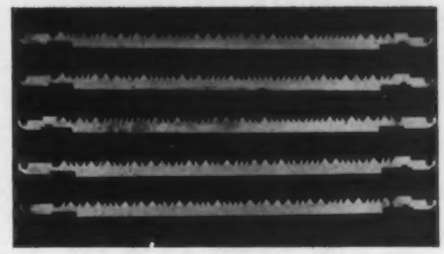


Fig. 1 Typical set of teleprinter combination bars produced by tape-controlled rack cutting

Tape-controlled machining at Creed

TELEPRINTERS EMPLOY 5-UNIT BINARY codes for the transmission of information, the particular code in use being determined by the geometry of a set of five sawtooth combination bars, of the type shown in Fig. 1. In communications work there is an international teleprinter code (CCITT International Code No. 2) and this is in general use at present. However, there are probably around 500 communications codes in all. Furthermore, there is no standard teleprinter code for data processing work and every British computer employs a different code. The increasing application of teleprinters as input-output devices for data processing systems can only add to the diversity of teleprinter codes in use.

Many small-batch runs

This means that Creed must manufacture a wide variety of combination bars on a small-batch production basis. Moreover, the racks must be accurate, or the 'touch' of the instrument will be affected. A number of fairly conventional machining methods have been used over the years, but as the problem became increasingly severe, it was decided to install a Koepfer rack-cutting machine.

The basic Koepfer machine has a work table which advances in steps—pitches of the lead screw—the head descending to cut the rack, step by step, in accordance with a programme bar. It follows that there must be a special programme bar for every type of combination bar. The manufacture and storage of a large number of programme bars is expensive, and the next stage was to make a special bar having a variable programme—pieces could be added to, or subtracted from the bar to suit particular codes.

In this way the problems of small batch production were overcome to some extent, but it was felt the situation could be improved still further if Creed's experience with punched tape as a medium for information storage could be utilized. Punched-tape control of the Koepfer rack-cutting machine has now been operating with great success for some months.

Punched-tape machining

The rack-cutting programme for the Koepfer is carried by $\frac{11}{16}$-in. wide, five-track punched tape, each of the five tracks holding the coding for a particular type of combination bar. In operation, the machine feeds the work table past the cutter in fixed steps. The work table halts at each step, the machine senses the programme and cuts or ignores the workpiece in accordance with the programme. It feeds forward pitch by pitch of the lead screw, the cycle of operations being repeated until the process is complete. The machine itself controls the feed of tape, whilst tape information controls the cut.

When working with a programme bar, as in the original design, the machine is governed by the setting of a skip contact. A skip bar attached to, and moving with, the work table, follows the profile of the programme bar and operates the skip contact when the skip bar falls into a valley on the bar. This instructs the machine to cut. If the skip bar is held up by the programme bar, the skip contact remains open, the cutting head is inoperative and the work table moves forward. Under punched-tape control, the skip contact operation is satisfied by a relay contact, the relay operating when a 'mark' condition on the tape is sensed by the peckers of the tape unit.

Operation under tape control

The operation of the Koepfer machine under tape control will be apparent from a study of the schematic diagram in Fig. 3. Direct current is applied to the 16 μF capacitor, this being charged through switch KS1, the indexing cam operated microswitch SW1, and 1000 ohms to frame. Once per revolution of the indexing cam on the rack-cutting machine, switch SW/1 is operated, so applying the capacitor's charge to the feed solenoid of the Creed model 92 tape reader. The tape is thus fed forward one pitch. 'Tape-out' and 'taut-tape' contacts in the tape reader, operate relay AR/2, contact AR1 preparing relay PR/1 for operation. If there is a mark on tape channel 1 and rotary switch RS is switched to that channel, relay PR/1 will operate, contact PR will open and the machine will cut at the pitch position. If the tape fails or is taut, relay AR will be inoperative,

Fig. 2 Single-headed Koepfer rack-cutting machine. The Creed tape unit is on the left

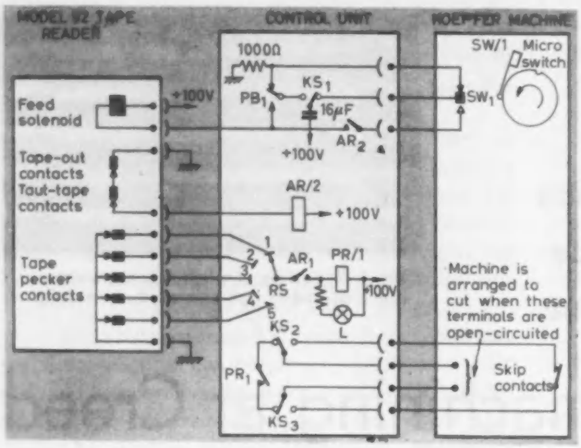


Fig. 3 Schematic diagram of tape-controlled rack cutting arrangement, comprising a tape reader, a control unit and the Koepfer. Key: PB, inching push button; SW, microswitch on indexing cam plate; KS, manual/auto switch—in auto position; RS, tape channel selection switch

contacts PR1 will remain closed and the machine will not cut.

The key switch KS, is the 'manual/auto' switch which determines whether the machine is tape-controlled—switch in rest position—or controlled by the original programme bar and skip contact arrangement—switch in operated position. When setting up the machine, switch KS must be in the operated position so that push button PB can be employed to 'inch' the tape to its start, or reference position, prior to cutting.

Creed are now using a double-headed Koepfer machine for producing combination bars under punched-tape programming. The second head is merely a slave, and CONTROL understands that it is rarely used; the setting up and production time for a normal batch using both heads, is the same, or even exceeds, the time taken to set up for a single head and produce the batch.

Much of the success of this form of programmed machining must stem from the fact that punched tape and a set of teleprinter combination bars are inherently alike. Both carry a teleprinter code and, therefore, it is not difficult to control one with the other. However, CONTROL understands that Creed & Co are actively seeking further outlets for tape control of this nature. They are already working on a tape programming system for cutting the slots in teleprinter ring cones. There is also some suggestion that certain rack-cutting machines may be offered with the Creed system fitted as standard.

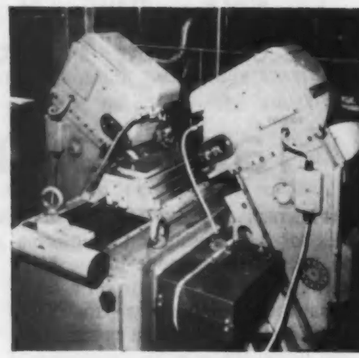


Fig. 4 Double-headed tape-controlled Koepfer rack-cutting machine—tape unit in foreground

CONTROL gathers that the total cost of fitting the Koepfer machine with punched-tape control, was around £200.

CONTROL IN ACTION

Air Conditioning A1 at Lloyd's

Electronics control the 'Room'

Fig. 1 Electronic control governs the air conditioning of the 'Room' in Lloyd's new Lime Street building

THE NEW LLOYD'S BUILDING IN THE CITY of London is remarkable chiefly for its underwriting room—the 'Room'. This great hall (Fig. 1) measures 340 ft by 120 ft and, with its all-round gallery, provides an area of over 44,000 sq ft. To air-condition such an expanse under normal conditions of occupancy is difficult. The long South wall is almost entirely glazed so that the solar gain varies with the time of day and weather. Different treatments on the other walls produce different rates of radiation loss. The main challenge to the heating and ventilating contractors, G. N. Haden & Sons Ltd, however, lay in the unusual conditions of occupancy of the building. The Room may throng at peak periods with up to 3000 people, while at others it may be comparatively empty. Moreover, the density of the occupation is not uniform.

In order to meet these stringent requirements, the heating and air conditioning consultants (Oscar Faber & Partners) decided upon a system in which heating and cooling, as well as humidity, are controlled by signals from 257 thermostats of the wet and dry bulb type.

The Room is divided into six zones, each served by an independent recirculating air conditioning plant with its own control system. Difficult zones are further sub-divided into localities, with auxiliary booster heaters in the air delivery ducts under local thermostatic control. The six recirculating plants are fed with a proportion of fresh air at dewpoint conditions at a rate of up to 25% of the total circulated volume.

To control the temperature and humidity in each zone, with rapid compensation for changes in occupation state as well as the effects of altering conditions in neighbouring zones, all plants are supervised by an arrangement of electronic controls by Honeywell Controls Ltd. Part of the basement

control room can be seen in Fig. 2. The long wall carries a schematic layout of the system, one panel being allotted to each main zone of the Room, and one to the fresh air system. The horizontal rectangle on each panel represents the air conditioning plant, with hot and chilled water circulation below and air circulation above. Meters indicate the percentage flow through the various hot and chilled water valves and air duct dampers.

Wet and dry bulb control

Each zone recirculating plant (see Fig. 3) comprises an electrostatic filter, a cooler battery and a heater battery, the batteries being served by chilled and hot water mains respectively. Air is delivered to the zone and returned for recirculation by way of a return air duct. Fresh air from the plenum is entrained between the heater and cooler batteries, the proportion being controlled by a motorized damper which is electrically coupled to the main fresh air plant output damper, to maintain constant pressure conditions in the plenum.

Primary control is by wet and dry bulb thermostats in the plant outlet duct. These are 500 ohm resistance units and are connected to two a.c. bridge circuits, with the thermostat forming one arm of the bridge. Out-of-balance voltages, due to alteration of thermostat resistance, are amplified, a phase discriminator determining whether the change represents increase or decrease in temperature. The output provides modulating control of the valves serving the heater and cooler batteries. The wet and dry bulb thermostats are of equal authority but a compensating signal from the return air ducts provides for zone occupation state. Outdoor temperature compensation is provided by outside wet and dry bulb thermostats, while an overall summer 'set-up' controller resets the system in hot weather so that inside temperature is raised above normal to a preset level below the outside temperature.

Control action

Signals from the controllers determine the rates of heat input and heat extraction of the heater and cooler batteries respectively. The dry bulb controller adjusts a three-way valve on the water supply to the heater battery, to vary the recirculation and therefore the temperature of the water flow. A dry bulb controller in sequence with this valve, adjusts the cooling water supply for sensible cooling by means of four motorized (Modutrol) on-off valves in parallel, each of which serves a separate bank of tubes in the cooler. The banks of tubes are of different sizes so that by the appropriate selection of valves, 10 different rates of flow can be obtained between 'all open' and 'all closed'. The selection of the valve combination is performed by a step controller, driven by a Modutrol motor which, acting on signals from the dry bulb controller, rotates the shaft and, therefore, cams. These operate 10 mercury switches to adjust the valves in sequence and provide graduated water flow.

Wet bulb control adjusts a three-way valve, via a modulating motor, to vary the proportion of recirculated and chilled water to the cooler battery. Additional wet bulb control is provided by a step controller which performs the same operations on the same on-off valves as the dry bulb step controller. The rate of flow through the cooler is determined by whichever controller has the higher demand.

Fresh air plant control

Electrostatic and viscous filters purify the fresh air intake, which passes through a pre-heater battery and saturating spray. A fan delivers the air to the plenum system feeding the recirculating plants. Signals from a dewpoint thermostat, control both heater battery and spray through three-way mixing valves. An outdoor thermostat resets the dewpoint thermostat to maintain substantially constant dewpoint conditions at 43°F at the fan entry.

A fresh air control damper governing the amount of air make-up to the recirculating plants, is electrically ganged to the recirculating plant dampers, and is also interlocked with extractor fans in the Room. These fans are switched through a step controller so that the fresh air make-up is balanced to the exhaust.

Additional systems

To reduce scaling in both heater and cooler circuits, each system is provided with its own pH control. A continuous balance electronic potentiometer measures the output of a glass/calomel electrode assembly in the water, which forms an electrolytic cell whose output is directly proportional to the pH factor. The balancing action gives a direct recording of pH, and operates a motorized valve governing the flow of caustic make-up from a storage tank into the water supply.

Wet and dry bulb temperatures, derived from resistance thermometers, and direct readings of relative humidity are indicated and continuously recorded by multi-channel Electronik recorders. The direct r.h. readings are obtained from relative humidity transducers. Moisture content of the air is sensed by changes in the conductivity of plastic elements on which a grid of gold leaf is

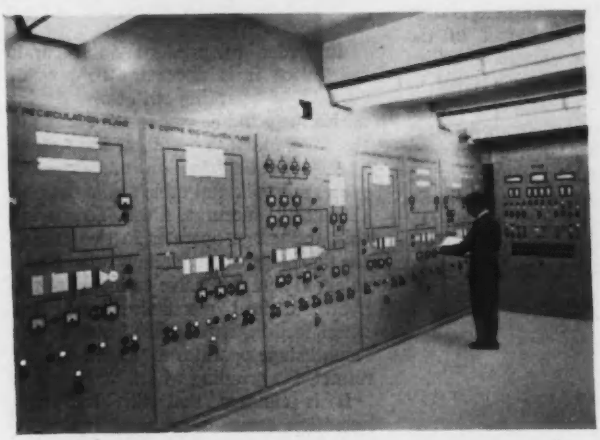


Fig. 2 A graphic panel forms one wall of the air conditioning control room

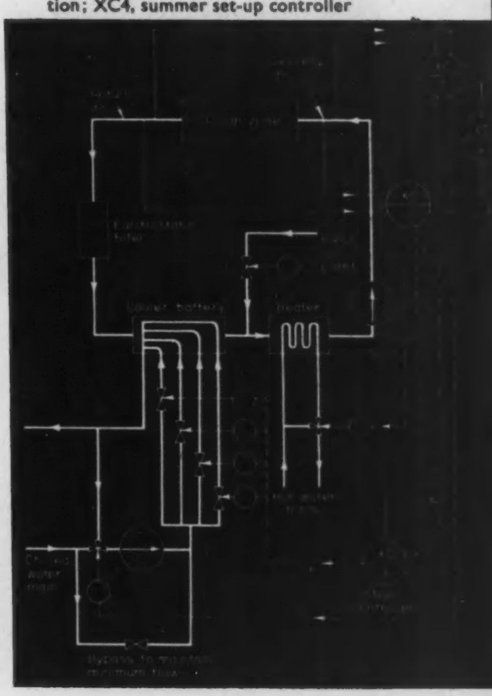


Fig. 3 Simplified schematic showing one of the zone recirculating plants and its controls. XC1, wet bulb thermostat controller; XC2, dry bulb thermostat controller; XC3, step controller; T1, T2, outdoor compensation; XC4, summer set-up controller

printed, the whole element being coated with moisture-sensitive lithium chloride salt. Eight separate elements, having temperature compensating resistance networks, cover the range from 35% to 93% r.h. between 40°F and 130°F.

The Electronik recorders are of the continuous balance type. Thermometer and transducer signals are automatically cycled to the measuring network, some recorders accommodating eight channels each, and others six. The recording head incorporates a rotating printwheel, with a different symbol and ink colour for each channel, the impressions being made on a vertically moving strip chart. The cycle time is 2½ sec per channel. With resistance thermometers, the calibrated accuracy and sensitivity are both within a fraction of 1% of the scale span.

Separate eight-channel instruments record wet and dry bulb temperatures, respectively, at each of the six recirculating plant outlets, at the fresh air plant outlet, and of the outside air. Three six-channel recorders present dry bulb readings at 18 points in the Room and other locations, while a further three, connected to the transducers, provide eighteen r.h. records.

CONTROL IN ACTION

Ford use automatic 'knock-off' gauging

Controlled machining of tractor shafts at Dagenham

THE FORD MOTOR CO RECENTLY INVITED CONTROL to Dagenham to see the production lines for the Ford 'Dexta' tractor. This provided an interesting insight into the high degree of mechanization common in the motor car industry, but little of control engineering interest was seen. However, we were shown the automatic gauging control of 'Precimax' Landis Lund machines grinding tractor transmission shafts. According to Ford, the automatic gauge guarantees finished diameters to within 0·0002 in., but the suppliers—Electronic Gauges Ltd—claim an auto-sizing repeat accuracy better than 0·0001 in. Of French origin, the 'Stop-Cut' auto-sizing device was introduced on the Continent about 10 years ago, and Electronic Gauges have operated the patent rights in this country for some four years.

Fig. 1 Placing the gauge head on a workpiece prior to grinding a transmission shaft for the Ford 'Dexta' tractor

Controlled wheel-feed

Fig. 1 shows a controlled grinder at Ford, the operator's left hand positioning the gauging head, whilst the indicator and electronic unit is at eye level on the right. The operation will be apparent from the schematic (Fig. 2). Basically it is an electrical bridge with the gauge in one arm, the gauging head consisting of a differential capacitor which is varied by a piston linked with the workpiece. If the workpiece is over size, mechanical displacement of the differential capacitor creates a bridge out-of-balance voltage which is fed to an amplifier in the electronic unit. As the workpiece is ground down towards the required size this voltage decreases and causes the current through a pilot relay in the anode circuit of an electronic valve to increase. At zero volts, the electronic valve triggers, causing a relief valve to operate and, through the electrohydraulic system of the machine, halt the feed-in of the grinding wheel.

The dwell period

In order to produce an accurate workpiece it is necessary to provide 'dwell' or 'sparking-out' time, during which the grinding wheel is not fed in to the component. The object is to allow the elastic deformation of the workpiece, tailstock and table to die out and thus give an accurate finish. To provide this, the gauge operates in two stages, the first stage causing relays operating a solenoid-actuated valve to interrupt the hydraulic feed mechanism and halt wheel feed-in, as described above; the second stage operates to 'knock-off', or retract, the grinding wheel.

It is claimed that this two-stage operation causes sparking-out time to be substantially the same, whatever the wear of the grinding wheel. This is because the lag between the first and second stages is preset by the operator.

The system makes it possible for a single operator to serve more than one machine. As an automatically-applied gauge head has now been developed, mechanized machine-loading would make the whole process automatic.

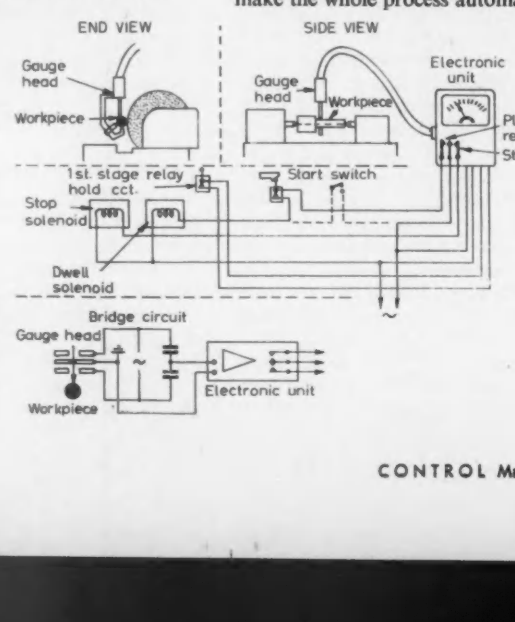


Fig. 2 Schematic diagram of a two-stage 'Stop-Cut' on a grinding machine. Note that both 'side' and 'end' views are given

A Correspondent summarizes the recent SIT papers and discussion

AUTOMATIC WEIGHT CONTROL

ON 24TH FEBRUARY, IN A PACKED LONDON hall, the Society of Instrument Technology held a symposium on 'Automatic Weight Control in Industry'. This dealt ealistically with experience in solving problems of industrial weighing, and ended with a virile discussion.

Three papers were read: **1.** 'A Survey of Batch-Blending Techniques,' by R. C. Peattie and R. N. Settle, of Henry Simon Ltd; **2.** 'An Electropneumatic Constant-Weight Feeder for Ore-blending,' by E. I. Lowe and M. J. Harris, of Imperial Smelting Corporation; **3.** 'Weighing Techniques for Automatic Production Lines,' by A. L. Hendon and G. T. Chapman, of Telomex and Solartron Industrial Controls, respectively. (Both these authors had influenza and the paper was read by E. Morris.)

Weighing batches

In a batch-blending system solid or liquid material usually flows from a bin to a weighing machine, the flow stopping when the necessary weight has passed. Flow control can be by a slide or other form of discharger at the foot of the bin. Peattie and Settle point out in their paper that the weighing machine itself may be analogue or digital. The analogue type—familiar as manual weighing machines—indicates by a lever system and scale pointer (though load cells and a self-balancing potentiometer may be fitted); while the digital type is an automatic weigher, having hopper, lever system and counterbalance, which discharges the hopper when its weight reaches that of the counterbalance. The digital machine thus provides only a fixed preset weight, and any required weight in the blending process must normally be an integral multiple of this. But in the Lindars type of digital machine the counterbalance can be varied discretely by solenoid-controlled weights. Automatic digital weighers can give accurately about 5 tips a minute.

Setting dials by hand on a panel is a convenient way of feeding in the necessary control information but use of punched cards is more reliable. In a digital weigher the control equipment counts the tips and stops the machine after the required number, or with a Lindars machine resets the counterbalance for the last tip.

Choice of transducer

For automatic control of a dial (analogue) machine a transducer must be fitted to the machine's pointer-spindle. This should be linear to one part in 1000, of low running torque, and have uniform performance through 350°, to allow a long scale. One type of digital transducer is the Rotapulse, which transmits a pulse for every pointer movement of a certain small angle, the pulses being counted on a decade counter. This is useful where the containers' tare weight varies, since material can be loaded into them until a certain pulse count—corresponding to the material only—has been reached. A second type is an ordinary shaft digitizer (*cf.* article on p 68), using a coded disk and photocell. But designing systems with such a digitizer to 'fail safe', and to allow compensation for varying tare weight, is not easy.

An analogue transducer such as a synchro or potentiometer can be used in many ways, e.g. through a torque amplifier. It can operate either limit switches on the dial face or a digitizer, the greater torque allowing simpler design of the latter.

Records

Requirements for automatically recorded information, e.g. by a digitally-controlled typewriter, influence the choice of control system. With cumulative weighing and a shaft-position digitizer, only the total weight can be printed easily, but with pulse systems batch records can be obtained. Digital counters can be used to give cumulative readings over say a week.

Peattie and Settle conclude their survey with a discussion of performance errors and plant design.

Weighing ore on a moving belt

Volumetric belt feeders were formerly used for regulating the feed rate of ore for blending at the Imperial Smelting Corporation's works at Avonmouth, but a check a few years ago revealed that they had serious errors. To improve performance, an electropneumatic

constant-weight feeder using strain-gauge load cells was designed, and Lowe and Harris describe this in their paper.

A short section of the continuous belt feeder is supported at either end by two idler rollers (see Fig. 1, where one idler is named 'head pulley'), and in the middle by a weigh roller suspended on chains from two load cells. The load cell

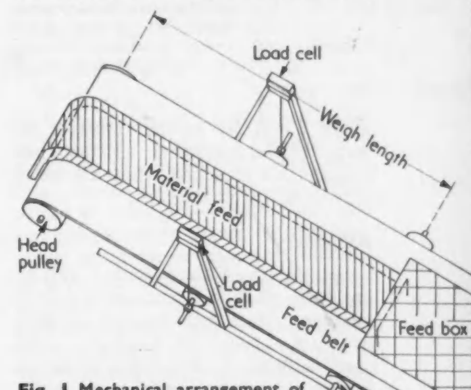


Fig. 1 Mechanical arrangement of a weighing system for controlling ore feed rate

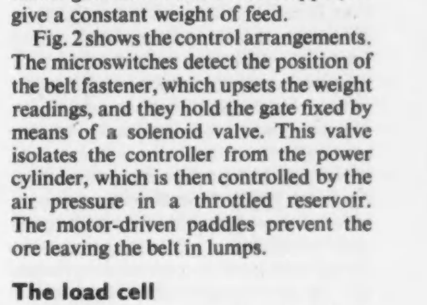
output is fed to a two-term potentiometric recorder-controller, which positions, via a pneumatic power cylinder, a sector gate at the exit of the hopper, to give a constant weight of feed.

Fig. 2 shows the control arrangements. The microswitches detect the position of the belt fastener, which upsets the weight readings, and they hold the gate fixed by means of a solenoid valve. This valve isolates the controller from the power cylinder, which is then controlled by the air pressure in a throttled reservoir. The motor-driven paddles prevent the ore leaving the belt in lumps.

The load cell

Originally an encastré load cell—a beryllium-copper strip clamped at each

Fig. 2 Schematic of the weighing system of Fig. 1



end—was used, but experience proved that its calibration was not linear, which prevented large numbers of the cells being installed, owing to the variable output matching required. Now cells of the proving-ring type are fitted. In this four gauges, cemented to a duralumin ring, are connected as a Wheatstone bridge. The maximum load for each cell is 150 lb, with an output for this load of about 6 mV. By adding resistors, the zero, slope and terminal resistance are brought to a standard, which allows all cells to be interchangeable.

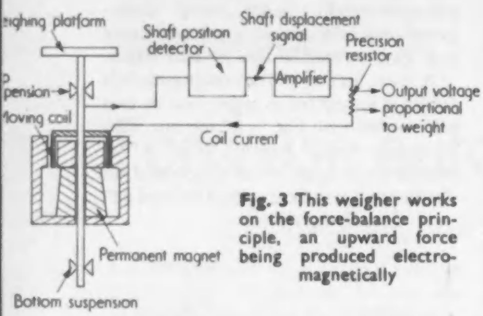


Fig. 3 This weigher works on the force-balance principle, an upward force being produced electromagnetically

Accuracy

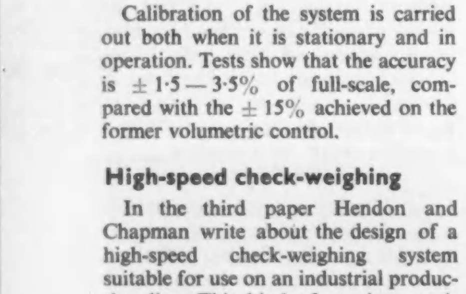
Calibration of the system is carried out both when it is stationary and in operation. Tests show that the accuracy is $\pm$ 1·5 — 3·5% of full-scale, compared with the $\pm$ 15% achieved on the former volumetric control.

High-speed check-weighing

In the third paper Hendon and Chapman write about the design of a high-speed check-weighing system suitable for use on an industrial production line. This kind of requirement is common today, when many food products have by law to be marked with a minimum net weight. Deliberately setting the weight high to allow for random variations is clearly uneconomical.

Normal beam scales have too low a weighing speed. Several other types of weigher are possible for high-speed check-weighing such as spring and liquid-displacement controlled machines, but the system favoured by Hendon and Chapman makes use of an electromagnetically produced restoring force, the current providing a measure of the applied weight. This system allows high weighing speeds, can give a continuous output proportional to weight if necessary, and makes possible compensation for over- and under-weight. Fig. 3 shows the arrangement schematically; a photoelectric or variable-reactance device picks-off the position of the shaft, and regulates the coil current by an amplifier. The coil, in a permanent magnet gap, produces an upward force on the weighing platform.

Fig. 4 The weighing-head used with an electromagnetic check-weigher in a Scribbans-Kemp biscuit factory



Limitation on weighing speed

In practice a system in which the maximum upward acceleration produced in the weight is only 1 *g* proves satisfactory. Over-critical damping is used to improve stability, which gives a rise time of at least 100 msec. But loss of speed is not at present important as the main speed limitation arises from mechanical handling; with a weighing time of 100 msec the authors state that a weighing speed of 150 per minute is practicable, the figure rising to only 200 per minute if the weighing time is zero.

A practical installation

The picture at the head of this article shows an actual installation for check-weighing biscuits. It works at a speed of 90–100 per minute with a discrimination of about 0·2%. The weighing head is inside the mechanical handling unit on the left. Electronic apparatus is housed in the cabinet on the right, while the meter and pen recorder on the far right display the running average weight.

The weighing head

Fig. 4 shows the actual weighing head. A pivoted beam with counterweight supports the lower end of the shaft; and an aluminium coil former helps to provide damping. The amplifier unit on the left handles the output from a photocell. Hendon and Chapman end their paper with more detailed consideration of the electronic control equipment, in which the valves are mainly of special quality to give maximum reliability.

Why check-weigh at all?

Opening the discussion, J. O. C. Vick, of ICI (Plastics), posed a very leading question in asking why one needs to check-weigh, instead of weighing accurately at the filling position. This produced several comments pointing out the lack of tare weight information when check-weighing. Morris replied that often the need for check-weighing arose because filling was done volumetrically and weight variations arose from change in product density. For example, on detergents it is not unusual to find a variation of ¾ oz in a 22 oz packet.

One user suggested that printing out digitally each actual reading from a check-weigher or weigher-filler would be an improvement, but this was immediately countered by another who deplored the production of yards and yards of paper carrying figures which would never be read. Perhaps there is a case for printing out variations from normal. Another significant use for print-out, which in D. C. Nutting's view is likely to become of increasing importance for packaging of goods for supermarkets, is the fast printing of a package's actual weight on a label, which would also have the extended price printed on it at the same time.

Filtering vibration . . .

G. H. Laycock, of ICI (Alkali), referring to the check-weigh paper by Hendon and Chapman, asked whether this principle had been applied to larger weights, and R. H. Tizard, of the London School of Economics, inquired into the effects of vibration and shock, particularly on knife-edge suspensions, and whether or not a mechanical or electrical vibration filter could be used. In reply, it was said that theoretically a hydraulic or pneumatic system analogous to the electromagnetic system could be applied to weights greater than 40 oz, but this had not been done by the authors. It was very difficult to exclude completely the low frequency vibration associated with most forms of moving machinery and the best solution was usually to mount the weighing head so as to use as much mass as possible in the support.

. . . and using it for feeding

G. M. E. Williams, of Combined Technical Services, asked Peattie to what extent vibrationary feeds had been used and what ways were available for improving batch consistency by, for example, fluidizing. Replying Peattie gave examples of use of brine instead of bulk salt, or pellet carbon instead of powdered carbon, so that the material was more amenable to regulation. There were, however, snags in using vibration feeds, particularly if the various components were in adjoining bins and any of them had a tendency to pack or bridge over.

Old and difficult

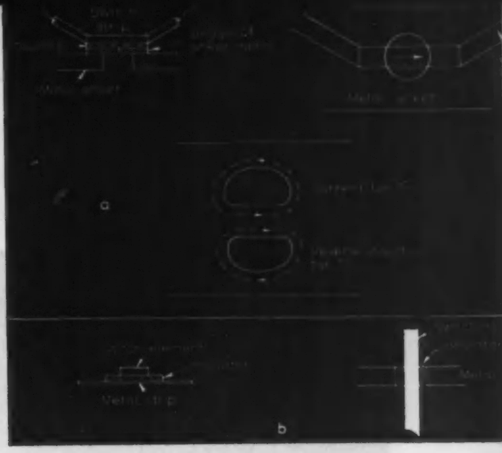
Summing up, H. H. Rosenbrock, the Chairman, said that although weighing was probably one of the oldest physical measurements, industrial weighing clearly had, from the papers and discussion, more than its fair share of the incidental practical difficulties. The symposium had ventilated some of these obstacles and would stimulate further work in them.

The illustrations are reproduced by courtesy of the Society of Instrument Technology

Computers are too fast for control systems—time sharing may be a way out

SPEARHEADS OF COMPUTER PROGRESS

E. A. Newman—of the NPL—reports an IEE discussion



How two superconductive devices work. a The Crowe cell developed by Lock; b A switch described at the Symposium

THE IEE MEASUREMENT AND CONTROL Section held some specialized discussion meetings about new digital computer techniques on 16th and 17th February. They were split into four sections on: Character Recognition; Peripheral Equipment; Low Temperature Storage and Switching Devices; and Special Aspects of Logical Design.

Digitally coded patterns

R. L. Grimsdale, F. H. Sumner, C. J. Tunis and T. Kilburn, of Manchester University, described a system of pattern recognition which seems to have great potential. They use a flying spot scanner to make a dot picture of the pattern as a matrix of 40×64 dots. A digital computer analyses this matrix, and produces a digitally coded description of the pattern in terms of the lines making it up, and their connectivity. AL for example might be described as a straight line length $\frac{3}{4}$ joined to one of length 1, and making an angle of 70° clockwise with it. The device recognizes patterns by comparing the description so obtained against a set of stored ones, and selecting the one giving the highest match score, provided this is sufficiently large. Pattern information can be fed into the computer accompanied by name information or information about correctness of recognition. Because of this stored pattern descriptions can be built up and improved in normal operation.

So far the scheme has been used for the recognition of handwritten print. It could—in theory—be used for any line pattern. The automatic recognition of line patterns can be useful to control engineers, who should therefore follow this development.

Ways of recognizing numerals

W. Sprick and K. Ganzhorn, from Germany, described a technique in which they recognize numerals by measuring variations in curvature down the front and back edges of them. The techniques used for measuring the curvatures were very ingenious, and the results claimed most impressive. In its limited field the system obviously has high promise. W. Dietrich, also from Germany, described an equipment designed to recognize typewritten numbers. This relied on measuring what parts of the inspected number occurred in the various parts of a matrix. The matrix was made up a strip at a time.

With one exception all systems described were thought to be capable of recognizing characters at the rate of several hundreds per second. W. K. Taylor, of University College, London, spoke about a development of a system he had described at the recent National Physical Laboratory symposium (CONTROL, December 1958, p 294). He hoped for speeds up to a million characters per second.

Punched and photoelectric tape

In discussing peripheral equipment, several people dealt with problems of producing and reading punched paper tape. Paper tape can be useful means of transmitting control information, and in automated systems of the future such information will probably sometimes be produced by digital computers, and at other times have to be fed into them. M. V. Wilkes and D. J. Wheeler, of Cambridge University, discussed some problems of the design of high speed photoelectric paper tape readers suitable for feeding information into computers. They claimed that it was important to be able to stop the tape between reading each character, and that the big difficulty was to achieve a quick stop time. Their technique is to float a piece of iron just above the tape, and bring it down electrically to act as a brake. In this way they have achieved reading speeds of 1000 characters per second. Readers working at 1000 characters per second use tape up quickly, and bring about a need for a sophisticated tape driving and spooling arrangement. B. G. Welby, of Ferranti Ltd, described suitable equipment, which made use of servo-driven spools fed via a vacuum operated tape reservoir.

Automatic graph plotting

M. P. Atkinson, W. T. Bane and D. L. A. Barber, of the National Physical Laboratory, gave an account of a device for plotting graphs automatically from digital information. The system works in rectangular coordinates, and uses a digital servo. As the plotting head moves along the axis electrical impulses are generated at fixed equal displacement intervals. These pass via a subtractor unit into a digital store, which originally has the position information fed into it. The head stops when the count is zero. This sort of technique has been used for controlling machine tools, and proved very useful.

In the system described the driving motors have three control positions: forward, backward, stop—dependent on whether the number on the store is positive, negative or zero. Stopping is by an electromagnetic brake, and takes only a few milliseconds. Scaling factors are produced by subtracting a number other than one from the stored number for every position pulse. Scaling factors between $\frac{1}{2}$ and 1 are given to ten binary places, and are derived by feeding the pulse in parallel to selected stages of the subtractor chain. Scaling factors less than $\frac{1}{2}$ are derived by moving the original stored number the appropriate number of binary places before starting. The number store and subtractors are combined in a neat transistor circuit.

Fresh ways of printing

There were some very interesting descriptions of new printers. K. G. Huntley and J. Hughes, of Rank Precision Industries, talked about xerographic printers. Xerography is a comparatively recent printing technique. Semiconductors have increased conductivity when exposed to light, but some such as selenium and zinc sulphide are quite good insulators in the dark. A

layer of such material on metal will hold an electric charge for some time, provided it is kept dark, but a light pattern if projected on to the charged plate will cause those parts receiving light to discharge owing to the semiconductor becoming conducting. The coated plate will now hold a copy of the pattern as a pattern of charge. Charged dye particles if drifted over the plate will stick to either the charged or discharged part of the plate, according to their own signs, giving either positive or negative images. Two techniques of printing are used. In one the semiconductor is on a paper sheet; ink sticks to the sheet, and is afterwards cooked in.

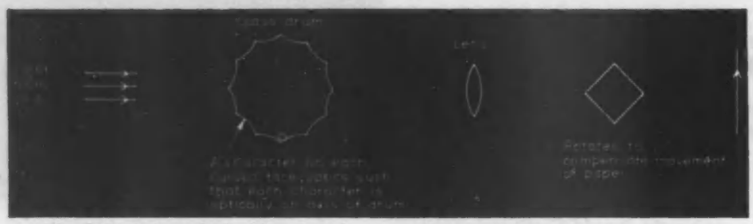


Fig. 1 Optical method of forming characters for use with xerographic printing

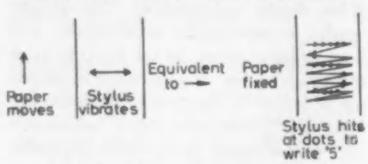


Fig. 2 Principle of operation of a high-speed mechanical printer, with a zig-zagging stylus

In the other technique the semiconductor is on a metal sheet, on which the ink pattern is formed. The ink is afterwards sucked off onto charged paper and then cooked in.

Huntley and Hughes suggested several ways of making characters as patterns of light. The one they prefer for very high speed printing involves writing the character in the form of dots on a cathode ray tube. The dots are selected by applying suitable deflexion potentials. They have achieved printing rates of over 5000 characters per second.

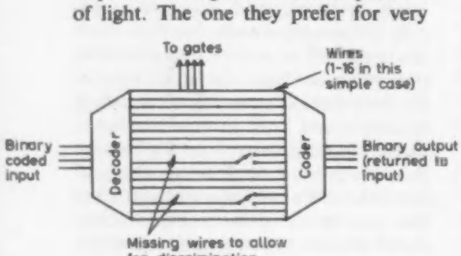


Fig. 3 Explanatory diagram of Wilkes's technique of wired-in programmes

G. G. Scarrott and J. A. Freer, of Ferranti Ltd, described another method of forming light characters, which could be used with a xerographic system. This is a mechano-optical system and its operation is shown in Fig. 1. The various characters are marked round a drum, and can be illuminated through an unfocused cathode ray tube directing light through a light guide. Characters are selected by turning light on at the right time. If the drum is long a row of characters can be printed by using a row of cathode-ray tubes. The optical arrangement keeps each character image stationary until the next comes into line.

J. H. Lucas described a high speed mechanical printer in which a printing stylus moves in a zig-zag fashion, and dabs on to the paper at suitable times. This is shown in Fig. 2. The time of dab must be recorded and stored in some way. Lucas, of Powers-Samas, explained a mechanical way of doing this, using in effect notched wheels controlling the stylus through a Bowden wire, and A. H. Ellson, of the same firm, outlined a system for controlling dabs by using a ferrite core. This system was very much faster than the mechanical one.

Superconductivity

In the session on low temperature storage and switching devices, K. A. G. Mendelssohn, of Oxford, talked about superconductivity. J. M. Lock, of the RRE, discussed some practical devices and O. Simpson, of the SERL, spoke about thermal time-constants.

At very low temperature—in the region where helium is liquid—some materials have virtually no resistance, and any current flowing, say in a ring of the material, carries on virtually for ever. An interesting feature of these superconductors is that the current they will take in a superconducting way is limited. By forcing current across the path of one already flowing—e.g. by inductive means—one can change the resistance of the material to the initial current from zero to a finite value. This gives the chance of making a very good switch. It also enables currents to be trapped in a superconductor, or taken out of it, and so enables it to be used as a store.

The diagram at the head of the article on p 89 shows some of the devices described by Lock. When these switch elements become resistive they dissipate heat, and warm up. This reduces the amount of current they will take as superconductors, and so an operation cycle must allow them time to reach their original state of coldness. Simpson spoke about this phenomenon. The control engineer might expect thermal time-constants to be long. In fact these devices are so small that they reach the correct working temperature again after a few millimicroseconds.

Elements using superconductivity would seem to have very interesting possibilities. Each element is extremely small and operates very quickly. By using them, it will probably be feasible to make a computer store of 10^7 bits capacity and average access time of less than 5×10^{-8} sec. Possibly one will be able to store analogue information in this way, and to alter connexions between units according to experience. But all this is in the future. Under laboratory conditions various kinds of units have been made which work, and which do change their state in small fractions of a microsecond. But it is early days, and no one knows what shocks, good or bad, they are keeping round the corner.

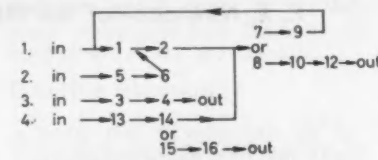


Fig. 4 A possible wired-in set of programmes used in the network of Fig. 3. (1), (2), (4) have parts in common; (3) is independent

Time sharing

In the final section C. Strachey talked about time sharing on a computer. In this technique a computer might be doing several problems virtually in parallel. If it needs then unavailable data for one problem, it automatically switches over to another, until the required data are available. Time sharing can be programmed on any computer, but can be very difficult to arrange. Strachey suggested design features in computers to make the task easier.

One difficulty about using computers in control tasks is that data are likely to become available too slowly for efficient computer operation. Making slower computers is no solution, since a slow computer costs more proportionally, and so to be really economic one should have a very fast computer and use it efficiently. Time sharing makes this possible when normal programming does not.

Wired-in programmes

It might well be that the best kind of computer to use for control work would be one with a wired-in programme. Wilkes pioneered extensive use of wired-in programmes—in fast general purpose computers. The technique he used is shown in Fig. 3. Information coded on a

two state wire, by means of a magnetic code decoding network, is made to energize one of 2^n wires, which when energized works a specified set of gates. Each wire also gives rise to a coded digital signal by means of a second core matrix and this signal can be fed back into the system. By this means a sequence of up to 2^n–1 events can be caused, and since each operates a set of gates a wired-in programme results. By adjusting the core matrices, a number of different sequences can be obtained. The total number of instructions must be less than 2^n, but sequences can have sub-sequences in common (Fig. 4). It is also possible to have discrimination facilities by decoding the original signals to less than 2^n wires, and letting a test decide which of the then spare inputs to the second matrix is used. G. Ord described a development of this device which has considerable limitations not found in the original, but which is capable of working very fast.

G. G. Scarrott, K. C. Johnson, E. Haley and R. Nayler described a circuit intended to find wide use in a computer system. The basis of this is a small current transformer having several primary windings. Currents can be passed through the windings in a positive or a negative sense. Only positive output signals are allowed, and these are limited to a standard value. Either information pulses, or continuous streams of pulses can be fed into any primary, and by ringing the changes on input connexions any kind of logical element can be obtained.

Pick-off

by 'UNCONTROLLED'

LAST month Imperial College was advertising for a lecturer for teaching and research in *control engineering*. I was glad to see this as evidence that the term is becoming more accepted in high places in this country. Whatever one feels about primary or secondary technologies, clearly servosystems + process-control + data-handling is now an engineering ground of fairly definite contour and needs a suitable name: 'control engineering' is the best short one. So far I have noticed only two British firms who include 'control engineering' or 'control engineers' in their notepaper heading. At the risk of appearing very unobservant, I give their names: Kinetrol Ltd and British Arca Regulators Ltd. But I shall be delighted to publicize any other firms who do the same, on hearing from them, even if that means crowding *Pick-off* with names next month.

I GATHER that the British Tabulating Machine Co are finding their Letchworth works, where computer-controlled production is used, very helpful in showing to hesitant customers the possibilities of automatic data-processing in the factory. This works, employing 400 people on the shop floor, was briefly described in last November's CONTROL. In fact, although this practical study of computer control was done primarily to improve production efficiency in respect of, e.g. stores held and plant loading, it is now proving a useful sales weapon. At present the factory is mainly making parts for card tabulators rather than computers, but nevertheless this 'making the punishment fit the crime' on the factory floor rather enthrals me—we are a stage nearer the self-reproducing machine on which Americans have recently been speculating. A surprising fact about the Letchworth factory is that the computer controlling its production is loaded for only eleven hours a week. This arises since other jobs have been deliberately barred from the computer, for the arrangement is of the nature of a pilot study. Mr Dickens, the Sales Manager of the Company, has said that 'the strength of the arrangement is that the accountant has been kept out of it'. But when these computers are sold to customers for their production problems, will the accountant be so easily excluded?

'Now they have a trainer that simulates the simulator that simulates the Comet . . . '

Courtesy 'De Havilland Gazette'

DIPPING again into Professor Macmillan's admirable little book *Automation: Friend or Foe?* published about two-and-a-half years ago, I was surprised how relevant the text still is. But the title now seems quite dated. Even if automation has not advanced as quickly as the popular Press led one to believe about the time the book was published, we have grown to accept the idea of it. Possible social evils arising from highly automatic industry now seem far more figmentary than those arising from normal trade cycles and from Government action, such as that which preceded the present recession in the aircraft industry. Not long ago Sir William Garrett, President of the British Employers' Confederation, was forecasting an increase in the labour force as a result of automation, and certainly much automatic control equipment is installed, without any aim of reducing labour costs. Moreover there is little Luddite feeling in the trade unions today, although union leaders do feel, naturally, that when any labour is likely to be displaced as a result of fitting automatic control employers should consult them as early as possible.

NO, if anything, Luddite feeling is to be found among established engineering firms who should know better. A friend tells me that a firm he knows making ships' steering gear feels it is being bludgeoned into collaborating with another making automatic helmsmen. It suspects that the helmsman's control system will break down and the steering gear will be blamed. The firm also believes that use of automatic control reduces the life of steering gear. I should think it is ripe for a take-over bid.

NEWS ROUND-UP

from the world of control

AIRCRAFT

Bo . . e . . ing

The automatic pilot is being blamed for the near-catastrophic dive of a Pan American Boeing 707 jet airliner which occurred on 3rd February. The aircraft, en route from Paris to New York with 124 passengers aboard, was 500 miles east of Gander when it fell from 35,000 ft down to 6000 ft. High-speed buffeting was experienced and a piece of wing fairing broke away. The aircraft then proceeded to its destination under manual control. Bendix, the manufacturers of the autopilot, say that subsequent ground testing of the autopilot showed it to be serviceable, apart from one minor relay which could not affect the operation, and that in airborne checks it gave all the proper answers.

CONTROL understands that the American Federal Aviation Agency are holding an official inquiry—presumably because they have designated the matter an accident—and it will be most interesting to see their verdict, if any. There are many different parties concerned with the affair, each with their own point of view. If Bendix prove that the autopilot was serviceable after all, was it human error? This suggestion will obviously be attacked by Pan American, but whether the American Air Line Pilots Association will ally themselves with the air line or not, is another matter. It must be remembered that the Association has been in dispute with Pan American over the crewing of jet 707s and DC-8s.

If neither autopilot failure nor human error, what of the aircraft itself? Boeing should not have much difficulty in extricating themselves from any suggestion that the aircraft was at fault, but it could affect their sales adversely. For example, BOAC have a number of 707s on order, and the Air Registration Board will, presumably, be watching the whole affair.

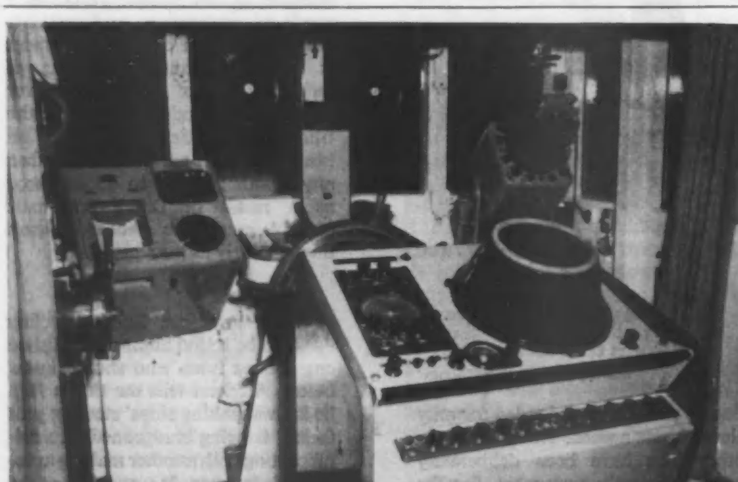
Yet another aspect: the Vickers VC10 is to be fitted with the Elliott-Bendix autopilot (Elliotts manufacture the Bendix instrument under licence in this country) and Vickers-Armstrong's Sir George Edwards takes a very stern view of aircraft equipment.

As the spokesman for a company competitive with Bendix in the autopilot field remarked, 'there but for the grace of . . .'

FOOD

Checking all 57 varieties

The food in a can, or tin, will quickly rot if the container has not been sealed properly. The seal efficiency depends on the butting together of the seams at the ends of the can, and the machine rolling these seams can drift out of its tolerance band to give a potentially bad joint. To prevent this drift, frequent random inspections must be carried out on the rapidly-manufactured tins. The firm of H. J. Heinz, worried by the long inspection times on the best existing machinery, approached Watson, Manasty & Co Ltd with a view to developing a new inspection method. The result was a can seam projector which has cut inspection times by almost half. The can is taken from a conveyor, and a section slit by machine. This is placed in the projector, which then shows on a screen a highly enlarged view of the seam. A chart placed over the screen enables a quick estimate of the efficiency of the seam to be made.



WATCH BELOW
Looking forward in the wheelhouse of the Kelvin Hughes research vessel *Lalla Rookh II*, which *CONTROL* visited last month. True motion radar type 14/16 is in the foreground, with a pedestal viewing unit to starboard of the wheel. A repeater from the transmitting magnetic compass (*News Round-up*, January) is at eye level in front of the wheel, and the echo sounding 'Fisherman's Asdic' to port. Kelvin Hughes are experimenting with an automatic helmsman based on the transmitting magnetic compass

WATER

Telecontrol

The fact that the Post Office hold a monopoly on communications in this country means that private radio telemetering between fixed points is not allowed. Frequency allocation problems is the given reason for this state of affairs, although it has been suggested that a vested interest in the telephone system may have something to do with it. CONTROL understands, however, that this situation may change soon, in which case, remote radio control of such public utilities as gas, water and electrical installations will be feasible.

Oasis control

Frequency allocation appears to offer little problem in the Persian Gulf, however, where the Qatar Petroleum Co intend using a remote control and indication system employing a v.h.f. radio link. The system, which is being manufactured by Gilmoor Control Systems (an Electroflo company), is to be employed for the remote control and position indication of 16 water pumps raising and transferring water from an oasis. The control system is seven miles from the pumps and amplitude-modulated control signals are transmitted at 173·5 Mc/s. Indications back to the control station are transmitted at 160·3 Mc/s, and two-way speech communication is by a frequency-modulated channel at 167 Mc/s.

Reservoir telemetering

The Exports Services Branch of the Board of Trade have called for tenders for reservoir telemetering equipment for South Africa. As the Board of Trade document, TEN/37320, is dated 13th February, and tenders should have been in the hands of the Town Clerk, Johannesburg, not later than 10 a.m. on Monday 23rd February, it

is difficult to understand how any British firm, without prior knowledge of the South African requirement, could possibly tender in time.

The telemetering system itself is, however, worthy of comment. A radio-operated system of recording in a central control station, the water levels of 10 reservoirs and four water towers was installed recently in Johannesburg, and the authorities wish to extend the system to incorporate a further reservoir, the Dunkeld. A level recorder and v.h.f./f.m. transmitter will be installed at the reservoir, and the recorder at the central depot must give a true indication of water level, resetting every 15 min. The extension will be incorporated in the existing system—a time duration impulse system—and use the same frequencies, 162·9 Mc/s and 167·9 Mc/s. The existing transmitter at the central depot will automatically trigger the Dunkeld equipment to transmit information in sequence with the other reservoirs. Alarms operable at dangerously low and high levels are to be added.

DATA PROCESSING

Connecting computers together

Certain large-scale data processing work requires faster computation than present computers can provide. One method of overcoming this lack of computing speed is to organize several computers into an integral network so that they can work together on a single task. The idea is to divide the total task into pieces, and have the individual computers of the network working on different pieces of the task simultaneously.

In practice, however, independent operation on differing parts of a task is not feasible because the results of one set of computations may be the input data for another set; the starting of one phase of operations must wait upon the ending of another phase. When successive phases are carried out by different computers, one machine may have to wait idly for data from another.

NBS Pilot data processor

These problems have been investigated by Leiner, Notz, Smith and Weinberger of the American National Bureau of Standards. They used queuing-theory techniques to evaluate the losses involved in one machine waiting for another, and to design optimum schemes for making the computers in the network share a common workload.

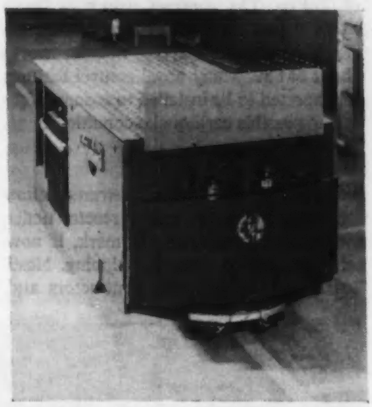
A simple network of two computers was set up, a primary machine, initiating joint transactions between the two, and a secondary, working on the demanded job. Meanwhile, the primary continues working on computations that do not require data currently being computed by the secondary.

The NBS Pilot data processor contains not only a primary and secondary computer, but also a third independent computer to control and interpret data flowing between the system's internal memory and its external storage and display devices. The NBS expect that further development will lead to even more machines cooperating in the performance of stringent tasks.

CONVEYING

Robotug for BR

The driverless trolley system—the EMI 'Robotug'—is on order by British Railways, and others at home and abroad, according to EMI Electronics. The system, which can



EMI 'Robotug' driverless trolley system fitted to a Scott Electric truck

be fitted to most types of truck, is of the magnetic leader cable type. A cable is laid along the specified route and fed with a.c.; sensing coils on the tractor interact with the magnetic field and cause the trolley to follow the cable.

Alf also interests

Development of Hunting Engineering's Alf (automatic line follower), a photoelectric system for converting electric trucks to automatic control, is also proceeding. Unlike the 'Robotug', which follows a magnetic cable, Alf senses a white painted line with the aid of photoelectric heads. Command signals—turn left, turn right, stop, wait for a given period, etc—may be provided by white dashes painted as a code alongside the route, or guide line. Two development prototypes are being built in conjunction with Conveyancer Fork Trucks, and these should be ready for demonstration in May. Apparently Hunting Engineering have received a number of inquiries from would-be users, but the outcome of these depends, of course, on the results of the demonstration.

MISSILES

Noise in guidance systems

The reward for those who attended Burt's lecture 'Theoretical studies of guided missile systems' was a clear, mathematical glimpse at some of the more complex problems which beset g.w. designers. The lecture was given before the Astronautics and Guided Flight Section of the RAeS on the 19th February.

He opened by dealing with the vagaries that enter servosystems when the control signal is so small that it becomes confused with the spurious signals from a number of sources, both inside and outside the main loops. These undesirable signals, or 'noise', form a confusing background to the control signals and make it difficult for the output (the missile) to follow the input (the target) exactly; the error can never be brought to zero and the missile will miss the target by a small amount. The problem is to minimize this mean miss-distance by juggling with the parameters of a particular guided missile system, that is by optimizing it. Burt briefly demonstrated the elements of the mathematics needed to tackle this optimization. He applied the principles to the problem of a missile flying low above the surface of a gale-swept sea, the varying height of the waves being considered as noise.

He went on to show the evasive behaviour which an enterprising target might adopt if it knew (by some method not explained) the missile's system, and its behaviour if it knew nothing about the missile. The increase in the mean miss-distance of the former over the latter was about 10%, perhaps not as much as might have been expected.

E. G. C. Burt, who is Senior Principal

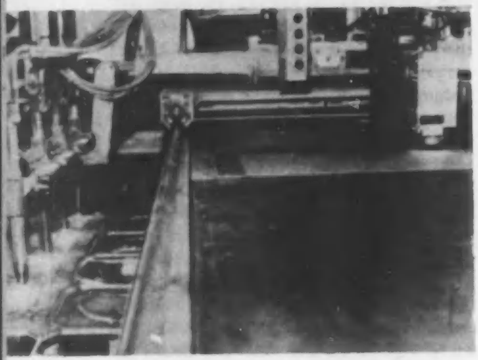
SQUARE-RIGGED MISSILE
The Seaslug ship-to-air guided weapon was shown to NATO military leaders at SHAPE recently, and this first official photograph of the weapon resulted. Destined for service in the Royal Navy's 'Hampshire' class g.w. ships, Seaslug already has a good record for accuracy. In one firing of a salvo of two missiles from HMS *Girdle Ness*, the first destroyed the target aircraft and the second made a direct hit on the largest piece of wreckage remaining. Seaslug is by Sir W. G. Armstrong Whitworth Aircraft, the control system by Sperry, and guidance by GEC. The guidance system is classified although known to be of the radar type. As HMS *Girdle Ness* is believed to carry two main scanners, however, it could well be that command guidance is used. A photograph of Seaslug being fired appears on page 54

Scientific Officer and Head of the Dynamic Analysis Division of RAE, concluded his lecture with a few wishful speculations on the guidance systems that might be used in launching a satellite.

MACHINING

Oxygen cutting control

Pencil line sketches of intricate shapes and forms can now be used to guide oxygen shape-cutting machines, according to the



Photoelectric tracer controlling an oxygen cutter from pencil drawings

Linde Department of Union Carbide. A photoelectric scanning head is geared to a steering motor which is connected by a geared belt to the drive head of the oxygen cutter. Automatic kerf compensation is said to eliminate problems of kerf width, so that reproduced parts are exactly the same size as the line drawing. Shape cutting is thought to be possible anywhere, regardless of lighting conditions, as the tracer is claimed to be insensitive to extraneous light and not to follow shadows. Stepless control of tracing speed from 2 to 30 in./min is provided by an eddy current governor and 90° turns of $\frac{1}{16}$ in. radius are possible at average cutting speeds. The new tracer will operate from line drawings that make the cutting torches move from one series of shapes to another, without interruption, for 'chain' cutting. Manual control is also possible.

According to Linde, savings accruing from the elimination of conventional templates alone, would pay for the photocell tracer in under a year.

EXPORTS

To West Germany

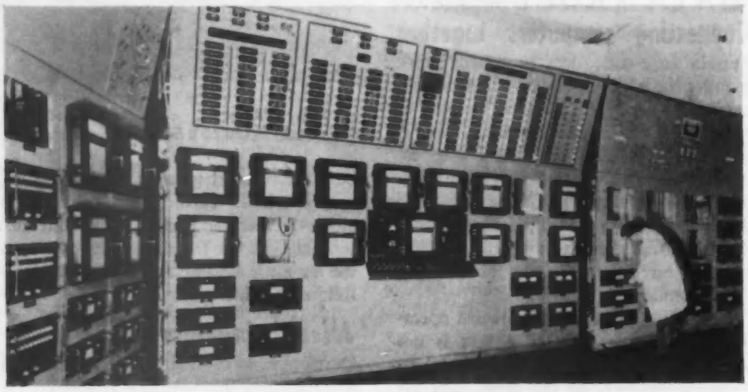
The Deutsches Elektronen-Synchrotron (DESY) Research Group, Hamburg, have ordered a 40 MeV electron linear accelerator, valued at about £250,000, from Metropolitan-Vickers Electrical. The Metro-Vick accelerator is to be used to inject 40 MeV electrons into a large electron synchrotron, which will further accelerate the electrons to 6000 MeV. Rigorous control of the M-V accelerator is necessary if this further acceleration is to be practicable; little variation from the specified 40 MeV is permissible and the electron beam must be compact and with little divergence. The Metro-Vick accelerator provides 2 μsec pulses at 125 mA, at a p.r.f. of 50 per second.

To Japan

GEC, in collaboration with Simon-Carves, have been selected to negotiate with the Japan Atomic Power Company for the building of Japan's first nuclear power station at Tokai Mura, 65 miles north-east of Tokyo. The contract, which is for a 150MW net station of the gas-cooled graphite-moderated type, will be worth about £M 30. Many novel control features are expected to be installed to ensure safety during possible earthquake conditions.

To Denmark

Ekco Electronics' nuclear instrumentation for the DR3 materials testing reactor under construction at Risø in Denmark, is now being dismantled prior to shipping. Head Wrightson are the main contractors and Ekco will cooperate with them in commissioning the reactor later this year. The illustration shows the fully-assembled instrumentation for the DR3, undergoing final adjustment at Ekco Electronics' Southend-on-Sea works.



The instrumentation for the Danish DR3 materials testing reactor

To Argentina

The University of Buenos Aires, Argentina, have purchased a Mercury high-speed digital computer, valued at about £150,000, from Ferranti Ltd. Although intended primarily for nuclear research work, the University will offer excess capacity on the machine to industrial organizations.

Ferranti have now sold 17 Mercurys, nine of them for nuclear research. Ferranti's computer exports to date—13 machines in all, including six Mercurys—have been worth about £M 2.

To Czechoslavakia

The Czech purchasing organization have ordered £10,000-worth of ultrasonic inspection equipment from Kelvin & Hughes for installation in a steel works. This 'Autosonic' inspection equipment is intended for the rapid scanning of rolled mild steel bars for internal defects, and consists of a remote control console containing cathode-ray tube presentation and recording equipment. This controls a scanning unit above the main feed conveyor. The installation will scan 7·9 in. dia bars moving at 98·5 ft/min, for internal defects, and mark and reject any bars containing defects in excess of a predetermined degree.

ELECTRICS

ASEE Show

Much equipment on the fringes of the control field will be shown at the Eighth Electrical Engineers Exhibition (Earls Court, 17th–21st March), and CONTROL cannot hope to mention more than a few exhibits taken, more or less, at random. Newman Industries (J1) will show their 'NEMA 66' frame $\frac{1}{4}$–$1\frac{1}{2}$ h.p. single-phase, and $\frac{3}{4}$–2 h.p. three-phase, motors, and also brake motors which incorporate an electromagnetic disk-type brake. Fractional H.P. Motors (L5) will exhibit examples of their standard range, as will BTH (K14), Lancashire Dynamo (E6) and Metro-Vick (A2); the latter will also show an interesting two-speed squirrel cage motor which incorporates a pole-modulated tapped winding.

Lancashire Dynamo Electronic Products (T1) will emphasize adjustable speed drives, including the 'Transidyne' fully-transistorized packaged Ward Leonard installations. BTH will show a transistor voltage regulator consisting of a Zener diode voltage sensitive circuit, transistor amplifier, rectifier for exciter field, and stabilizing circuit, for use with alternators of up to 100 kVA capacity at 50–60 c/s.

Components

Turning to components: Honeywell Controls (W3) will show type SX 'sub-sub-miniature' switches measuring 0·5 × 0·35 × 0·2 in. and weighing 1/28 oz, various limit switches and, of course,

heating controls including two-position and modulating temperature and pressure controllers. Londex (G3) will show a complete range of automatic electrical controls, with relays taking pride of place. Apart from the many different relays, Londex will exhibit a photo-transistor counter, a smoke alarm device, a battery-less supply failure alarm, air flow switches, pressure switches, process timers and level control systems. Electrical Remote Control Co (M8) will show electrical timing and control equipment, including miniature synchronous cam-operated timers. Sunvic (G11) will demonstrate their TQB water-heater thermostat, controlling an immersion heater in a lagged cistern. Thermocouples connected to a strip chart recorder will indicate the heat gradient in the tank, and also the operating cycles of the thermostat. The 6,000,000th 'Simmerstat' will be on view.

D. Robinson & Co will display Clifford & Snell plug-in relay systems on Stand Q14. Two new units are a plug-in latching relay and a plug-in electronic slugging unit. The latter will delay the operation of a relay for up to 2½ min. (up to 2 hours if an external capacitor is added)—a most inexpensive (£12) timer. Rodene, also on Stand Q14, will show a range of process timers and a potentiometer controller which incorporates two self-clutching motors, and has application in bridge balancing.

Elliott-Automation (L14) will exhibit many components, including panel instruments and recorders, tachogenerators, an a.c. gyroscope, and relays. Brookhirst Igranic (N4) will show 'static control units' (magnetic amplifier devices), switchboards, magnetic amplifier drive of a f.h.p. motor, and crane and machine tool controls. Metro-Vick will display control equipment including push-buttons, limit switches, switchboard instruments and a mine-hoist chart recorder which records the extent and duration of all movements and standing times of a mine hoist. Among the Stone-Chance (Y14) exhibits will be an Austinlite cyclic switch of the type fitted in the tail of the Vickers Vanguard for operation of the Napier 'Spraymat' de-icing system.

Other exhibitors will include Nife Batteries (K2)—batteries for switchgear operation including cells concerned with automatic train control, Langley London (K8)—electrical insulating materials, CIBA (ARL) Ltd (T8)—'Araldite' epoxy resins, Rosite (V5)—cold moulded insulating materials, and Hirst Electronic—welders and ancillary equipment.

Controlled entertainment

'Aurama', a *Son et Lumière* type of entertainment, will be presented at the Exhibition by Atlas Lighting on behalf of the ASEE. Stereophonically magnetic-tape-recorded music—Tchaikowsky's 'Fantasy on the Tempest'—will be blended with light and colour to provide a fascinating spectacle.

In Aurama, lighting signals are superimposed on the sound track, each signal firing a pair of thyratrons, momentarily. The output of the thyratrons during the conducting period, provides a d.c. signal which is distributed by stepping switches to one or more of 30 dimmer units. These incorporate thyratrons and feed each lighting circuit. The grid of each dimmer unit thyratron, is controlled by a phase-shift circuit, one leg of which is a capacitor and the other a photoconductive cell; the thyratrons conduct when light from an exciter lamp falls on this cell. The exciter lamp is in the anode circuit of a hard valve whose grid is controlled by two further photoconductive cells; one determines the intensity of the exciter lamp (and therefore the level of the lighting) whilst the other determines the time taken to reach this level. A common exciter lamp illuminates both these cells, and the lighting change is initiated as frames of a film medium are moved between cells and lamp.

IN BRIEF

● **Instruments and controls** exhibition at Bennett Hall, YMCA, Snow Hill, Birmingham 4 (17th-20th March) will have exhibits by W. G. Pye, Elcontrol, Cossor Instruments, Sodeco Counters, Lock Instrumentation, Southern Instruments, Loma Metal Detectors, British Physical Laboratories, Evans Electroselenium, and Thomas Industrial Automation. Tickets from A. M. Lock & Co Ltd, Newborough Road, Shirley, Solihull, Warwickshire.

● **Electronics and Communications** Section is the new name for the IEE's Radio and Telecommunication Section.

● **Analytical Instruments Department** has been formed under General Manager W. B. Horner, by Southern Instruments. The new department will be responsible for polarographic instruments and other analytical electronic tools, including the Sigrist and Weiss (Zürich) photometer for absorption and turbidity measurement.

● **Magnetic flowmeter,** the 'Altoflux', is being made to British Standards in this country by Alto Instruments (GB) Ltd.

● **Vibration-environment laboratories** are to be opened by W. Bryan Savage (17 Stratton Street, London, W1.) on 31st March.

● **BritIRE television convention** (Cambridge, 1-5th July); the 4th Clerk Maxwell Memorial Lecture will be given by Vladimir K. Zworykin. S. K. Mitra, an ionosphere authority, will also participate.

● **Silicon rectifiers** by Ferranti Ltd have been reduced in price some 23%.

● **IBM** World Trade Laboratories (Great Britain) Ltd have formed under Managing Director W. S. Elliott, for research and development in data processing and computers. Present address: Hursley House, near Winchester, Hants.

LOOKING AHEAD

A diary for the next three months

Unless otherwise indicated, all events take place in London. BCS British Computer Society. BritIRE British Institution of Radio Engineers, IEE Institution of Electrical Engineers. RAeS Royal Aeronautical Society. SIT Society of Instrument Technology

TUESDAY 17–THURSDAY 19 MARCH
Eighth Electrical Engineers' Exhibition. Sponsored by the ASEE. Earl's Court

WEDNESDAY 18 MARCH
Approach to Learning and Teaching Machines C. E. G. Bailey BCS 6.15 at the Northampton College of Technology, EC1

THURSDAY 19 MARCH
Long Range Missiles E. C. Cornford RAeS 6.00 at the Institution of Civil Engineers, Great George Street, SW1

WEDNESDAY 25 MARCH
Papers on Radio Telemetry BritIRE 3.00 at the London School of Hygiene, Keppel St. WC1

MONDAY 6–THURSDAY 9 APRIL
Ergonomics—Its Place in Industry Conference of the Ergonomics Research Society at Oxford. Details: Dr S. Griew, Department of Psychology, 22 Berkeley Square, Bristol, 6

16th Annual Radio and Electronic Component Show organized by the Radio Electronic Component Manufacturers' Federation to be held at Grosvenor House and Park Lane House, W1. Admission by invitation only

MONDAY 6–FRIDAY 10 APRIL
Fifth International Instrument Show. Organized by B & K Laboratories at 4 Tilney St, Park Lane, W1. Free tickets on application

TUESDAY 7 APRIL
Symposium on Large Capacity Storage Systems BritIRE 6.30 at the London School of Hygiene, Keppel Street, WC1

THURSDAY 16 APRIL
Self Optimizing Control Systems for a Certain Class of Randomly Varying Inputs. A. P. Roberts SIT 6.00 at Manson House, Portland Place, W1

THURSDAY 16–THURSDAY 30 APRIL
22nd Engineering, Marine, Welding and Nuclear Energy Exhibition. Olympia

TUESDAY 21 APRIL
The Problem of Maintenance of Electronic Equipment in the Process Industries (Discussion) IEE 5.30 at the Institution

MONDAY 27 APRIL
Electronics of Guided Missiles RAeS 6.00 at the Institution of Civil Engineers, Great George St, SW1

WEDNESDAY 29–THURSDAY 30 APRIL
Convention on Thermonuclear Processes. IEE. At the Institution

WEDNESDAY 6 MAY
Presidential Address by J. F. Coales SIT 5.30 at Manson House, Portland Place, W1

MONDAY 11–WEDNESDAY 13 MAY
Joint Symposium on Instrumentation and Computation in Process Development and Plant Design. Details: General Secretary, Institution of Chemical Engineers

TUESDAY 12 MAY
Early Experience with an EDP Installation T. C. Hickman BCS 6.15 at the Northampton College of Technology, EC1

THURSDAY 21–WEDNESDAY 27 MAY
International Convention on Transistors and Associated Semiconductor Devices. There will be a technical exhibition associated with the Convention. Earl's Court

LOOKING FURTHER AHEAD

MONDAY 15–SATURDAY 20 JUNE
International Conference on Information Processing. Organized by UNESCO in Paris. Details: Hon Secretary, Group B, BCAC, c/o IEE, Savoy Place, WC2

PEOPLE IN CONTROL

by Staffman

On hearing that **Lord Halsbury** was leaving NRDC to become Vice Chairman of Lancashire Dynamo, I asked him if LD were entering the computer field. He lectured me on the ethical considerations involved, saying 'How can a man who has been in the confidence of all computer manufacturers betray that confidence?' Lancashire Dynamo themselves seemed to be unaware of any impending attack on the computer market, although they have made ancillaries for computers in the past. **J. C. Duckworth** will be NRDC's new MD with **D. Hennesey** as Deputy MD.

SIM
Magnetic drive

JORDAN
40 light years on

The refreshing vigour with which Henry Simon's **R. C. Peattie** defends his company's interests (see *Letters to* CONTROL, page 47), plus the fact that the mention of EMI and Henry Simon in juxtaposition, rang a faint bell, aroused my curiosity. A little research revealed that EMI Chairman **J. F. Lockwood** is a director of Henry Simon. He has been with Henry Simon since the 1920's, becoming Chairman and Managing Director of the company in 1950. I believe that for a period he chaired both companies simultaneously. His presence on both boards means that healthy competition between the two will be on a friendly basis, although there can be no doubt that his 30-odd years in food engineering can only help EMI in their attack on the process control market.

R. C. Steel, Servomex Controls' live-wire Chairman and MD, is tremendously enthusiastic about his company's agreement with Feedback Ltd. Steel is now on the Feedback board where he joins CONTROL consultant **J. H. Westcott** (Chairman), **P. F. Blackman, T. J. Strand** (MD) and **J. Merrett.** Feedback's major interests lie in the educational field and I gather Servomex are to manufacture and market such Feedback designs as servomechanism components and assemblies, as well as apparatus for servosystem analysis and demonstration. Westcott tells me that so much effort is expended on making laboratory experimental equipment work, that the reason for the experiment may be lost on the student. Knowing the problems, Feedback plan to produce reliable demonstration equipment. Incidentally, Servomex have a new Production Manager, **J. P. Flowerdew.**

The American Embassy's new Science Officer—Scientific Attaché in diplomatic parlance—**Thomas H. Osgood,** was born in Lincolnshire and I thought that sufficient excuse for asking him about his new duties. As he had only been in this country for three days he was somewhat vague about them himself, but presumably they are no more sinister than those of the more conventional military, naval and air attachés.

WILLSHER
An electronic accent

FLOWERDEW
Servos for students

'The semiconductor is far behind the cold cathode tube for control systems purposes', Hivac's **J. R. Hughes** told me when I asked him how the transistor-valve battle was going. Hughes is now a director and Commercial Manager of Hivac Ltd—an AT & E company.

The BritIRE having announced that **Eric K. Cole,** Chairman and Managing Director of the Ekco companies, is to be elected an Honorary Member of the Institution 'in recognition of his services to the radio and electronics industry and profession', I attempted to obtain his reaction. Two weeks after the announcement, however, the BritIRE had apparently still not told Cole of their intention to honour him, and even I could hardly expect him to comment on something of which, officially, he knew nothing.

HALSBURY
Business ethics

OSGOOD
Lincolnshire poacher?

COLE
Honoured but unsung

Westool Ltd manufacture Warner electromagnetic clutches and brakes in this country, under licence from Warner Electric Brake and Clutch Co, USA, so I was not surprised to hear that **Stephen P. J. Wood,** Warner's President, had joined the Westool board. The board Chairman is **B. A. Williams** who was recently appointed a Commander of the Order of the Crown of Belgium, for his services to Belgian industry. Westool's General Manager **John Sim** was appointed in February; he was with the Vickers group and latterly with Oliver Pell Control and Varley Magnet.

After 40 years with Strand Electric, Works Manager **H. O. Jordan** has joined the board. I asked him about control systems and lighting equipment, but apart from mentioning the continually increasing interest in remote control he was reluctant to commit himself—'although there's a lot going on.'

Technograph's new technical salesman, **Peter Alsop,** an ex-EMI man with much experience of printed circuit technique, sees a great future for printed components. 'Printed resistors already exist and although capacitors and inductors may need a little more work, we'll get there. The future of components is bound up with chemical milling and electro-deposition.'

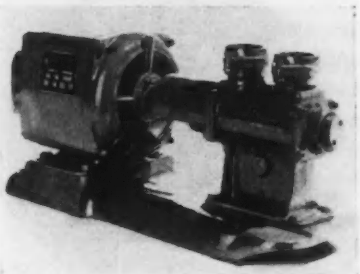
J. F. Willsher, who is now General Manager of George Kent—his predecessor, **J. Horridge,** having been obliged to retire because of ill health—tells me that 'the accent is definitely towards electronic control systems, with some support from the pneumatic and hydraulic sides. By the way, I was surprised to learn that Kent's steering gear division—an entirely separate production organization whose products are marketed by Cam Gears Ltd—accounts for about two-fifths of Kent's turnover.

New for Control

A monthly review of system components and instruments

PROCESS PUMPING SET
a light unit with output of 5 gal/min

A light-weight pumping unit has been announced by Goodyear Pumps Ltd. It is specially designed for food and chemical processing applications, factory and laboratory installations, and it is also suitable for general pumping duties. To a Goodyear size A5 positive-displacement pump is coupled a Newman 'Elf' ¾ h.p. a.c. electric motor mounted on an aluminium bedplate



Specially designed for food and chemical processing applications

casting. The pump, with a normal operating speed of 1440 rev/min, delivers 5 gal of water/min. It is self-priming, can run with a dry suction for long periods, and is also capable of handling viscous fluids and fluids which contain suspended solids. The Goodyear A5 rubber-to-metal type pump has only two moving parts in contact with the liquid, the plate wheel and rotor. The taper roller bearings are grease packed for long life, and high efficiency radial face shaft seals are fitted which do not cause the shaft to wear as they become due for renewal, as with a packed gland.

Tick **No 161** on reply card

INDUCTION DIGITIZER
a new type of transducer

The GEC induction digitizer is claimed to be an entirely new type of transducer for use with digital data handling and computer systems. It gives a numerical representation of the position of a shift or slide in the form of coded electrical signals without using slip rings, commutators or photocells. It is basically a transformer with a single excited winding and a number of secondary windings corresponding to the number of digits. The position of moving yoke decides the polarity of coupling between the excited winding and the various digit windings which are arranged to conform to the requirements of the code. Pulse or sine wave excitation can be used. Shaft digitizers can be operated in coarse-fine combinations; an additional winding prevents ambiguity between the digitizers. Instruments for 5-digit read-out in a size 11 standard synchro housing, and for 7-digit read-out in a size 23, have been made. A binary coded decimal form of the size 11 instrument has been made, one instrument being required for each decimal digit. The type LD5-2 has a shaft input, a resolution of 1 in 20 for a single instrument, and a nominal output of 1·5 V r.m.s. max. The type LD5-3 has a shaft input, a resolution of 1 in 32 for a single instrument, and a nominal output of 800 mV r.m.s. maximum. A typical excitation for the first type would be 10 V r.m.s. at 20 kc/s, and for the second 8 V r.m.s. at 20 kc/s.

The digitizer is handled by the Electronics Division of GEC.

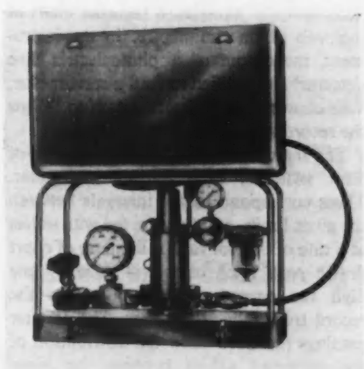
Tick **No 162** on reply card

HYDRAULIC TEST SET
automatic pressures up to 10,000 lb/in^2

The Madan portable hydraulic test set has been designed to carry out a hydraulic pressure test on a site, and the set only needs to be connected to a compressed air line as a source of power. On isolated sites where no compressed air line is available the set may be operated from nitrogen or compressed air bottles. The pump works on the principle that the air pressure applied to a large air piston imparts a thrust to a hydraulic ram of smaller area and creates a high hydraulic pressure. This reciprocating action gives a continuous flow.

The set operates from an air supply of not more than 100 lb/in^2. An air pressure regulator control valve is incorporated which enables all intermediate hydraulic pressures within the range of the pump to be accurately determined and which makes

A light, portable hydraulic test unit



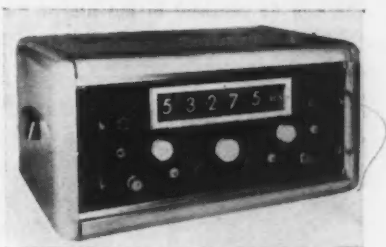
it completely safe for the operator to leave the item under test, as the desired test pressure is never exceeded. On reaching the necessary pressure the pump becomes dormant on a closed circuit, using no further air. Should there be intermittent leakage from the component or circuit under test, the pump will move automatically until the loss is made up. The pump is available in six models covering pressures from 50 to 10,000 lb/in^2.

The overall size ready for carrying is 21 in. long × 16 in. high × 8½ in. wide and the complete set weighs 38 lb. The set is made by Charles S. Madan & Co Ltd and it is claimed that the delivery is generally ex-stock and in no case will exceed 2 to 3 weeks.

Tick **No 163** on reply card

TIME & FREQUENCY MEASUREMENT
a versatile equipment

The time and frequency measuring equipment (type TSA53) just produced by Venner Electronics Ltd is completely transistorized and incorporates a new form



Uses a new form of digital display

of optical digital in-line display. The period measurement is from 0·000 01 c/s to 10 kc/s; and time measurement is from 1/10,000 sec to 11½ days; and frequency measurement is up to 100 kc/s. The accuracy exceeds 0·005%. The display time is variable from ½ to 5 sec or infinite, and a facility is provided for printer operation. Six standard output frequencies are available. The weight is 52 lb and the power supply can be 200/250 V a.c. 50 c/s or 12 V d.c.

Tick **No 164** on reply card

HYDRAULIC ACCUMULATOR
piston uses cushioning device

The details of a new liquid sealed hydraulic accumulator have been announced by Industrial Hydraulics Ltd. The unit

is of the gas-loaded piston separator type, and is available for capacities of 1, 2, 3, 4, 6, and 8 gal, suitable for working pressures up to 2000 lb/in^2. The body is constructed of seamless steel tubing with honed, polished and chromium plated bore. Heavy steel end covers are retained by high tensile alloy steel tie-bars and nuts. A feature of the design is the hydraulic cushioning device fitted to the piston. This acts firstly as a dash-pot damper to eliminate shock at the end of the piston travel when oil is withdrawn from the accumulator. Secondly, it seals off a small volume of oil which prevents the piston from coming into contact with the end cover; this oil is maintained at a pressure very slightly above that of the gas charge even though all pressure is released from the hydraulic system. During a period of shutdown, therefore, it is impossible for gas to escape into the hydraulic system, since any leakage past the piston seal must be in the reverse direction under the small differential pressure mentioned above.

Tick **No 165** on reply card

MINIATURE COMPONENTS

adjustable inductance and pot core

A new miniature toroid assembly has a high frequency adjustable inductance with a high Q-factor. The inductance adjustment is obtained by reluctance variation and the range of adjustment is about 10% according to the overall size of the core. The tuning law is linear and advantage of this can be obtained in the use of the adjusting slug as a proximity device. The

The size of the components is well shown by this photograph

thermal and mechanical stability of the tunable toroids is claimed to be good.

Another new development from the same firm is the miniature ferrite printed circuit pot core assembly. This assembly, which is enclosed by a ½ in. sq. can, has been developed for transistor circuits, in particular where printed circuits are employed. The components are all selected to operate under tropical conditions without deterioration of performance. The cores can be supplied in several grades of ferrite according to requirements dictated by inductance required and frequency of operation. Q's of 200 are obtainable at the lower frequencies and at 20 Mc/s Q's of 100 can be obtained. The pot cores have been used up to 40 Mc/s. The low frequency assemblies can be wound to give 11 mH inductance up to 4 Mc/s with correspondingly less as the material permeability is reduced for higher frequency performance. The temperature coefficient of permeability can be made for the assembly, less than 100 parts in 10^6/deg C.

These products come from Neosid Ltd.

Tick **No 166** on reply card

TRANSISTORS

an increase in a.f. ratings

The GEC Semiconductor Division has increased the maximum junction temperature of its range of audio frequency transistors from 65 to 85 deg C. As a result of this increase, the maximum collector dissipation of the low power transistors GET 103, GET 104, GET 106 and GET 114 is increased to 200 mW at temperatures up to 45 deg C (formerly 150 mW up to 35 deg C) and 150 mW up to 55 deg C (formerly 50 mW).

New ratings for the medium power transistors GET 105, GET 110, GET 115, GET 116, and GET 120 are: for the transistor in free air, 440 mW up to 45 deg C (formerly 330 mW up to 35 deg C) and 330 mW at 55 deg C (formerly 110 mW). With the transistor mounted on a 3 in. × 3 in. cooling fin, 800 mW up to 45 deg C (formerly 600 mW up to 35 deg C) and 600 mW at 55 deg C (formerly 200 mW). These new ratings are higher than those normally associated with transistors of this type, having an alpha cut-off frequency of 1 Mc/s.

Tick **No 167** on reply card

CHART ANALYSER

automatic, precise

The Cambridge automatic chart analyser can be used in industrial quality control where it may be necessary to determine the percentage amount of material which falls within given tolerances. The analyser automatically 'samples' a recorder chart at intervals of one millimetre. In the instrument, the output of a photoelectric 'line detector' is amplified to feed a servomotor. This causes the line detector itself to follow the record as the chart moves past it.

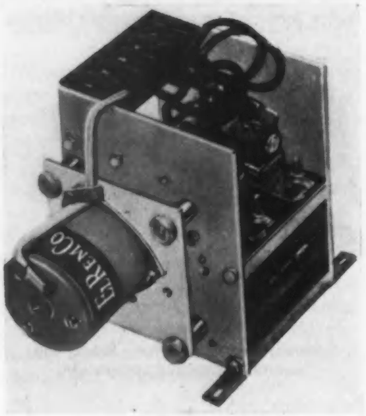
The servomotor also operates a series of limit switches, each feeding a counter. These correspond to the intervals between the given limits, and they are fed with pulses at a rate of one for each millimetre of chart drawn past. Each pulse will raise by one digit the counter in whose section the record trace falls at the time. The counter readings therefore show the distribution of the measured values between the given limits. Percentages are derived arithmetically. The maximum chart speed (6 in/min) is automatically decreased as necessary for the line detector to follow the steeper trace slopes.

Tick **No 168** on reply card

ELECTRIC TIMER

an entirely new type

What is claimed to be an entirely new type of timer has been introduced by the Electrical Remote Control Co Ltd. A motor-driven camshaft operates directly a number of tilting mercury tubes. For timing cycles of over 30 sec duration the mercury tubes are placed on tilting platforms with a snap action mechanism. On faster timing cycles



The motor-driven camshaft operates directly a number of tilting mercury tubes

the snap action mechanism is unnecessary, the cams directly operating the mercury tube platforms.

The timer can be supplied for practically any shaft speed between 1 rev/sec and 1 rev/28 days, and for a wide range of a.c. and d.c. voltages. The mercury tubes permit frequent switching of highly inductive loads of up to 30 A at 440 V a.c. or 220 V d.c. Any number of cams and mercury tubes can be fitted.

The prices range from £8 10s. and deliveries of small quantities can be carried out within 6 weeks.

Tick **No 169** on reply card

DIGITAL VOLTMETER

first in quantity production

A new digital voltmeter (model D101) covers the range quantity 0·01 to 999 V d.c. with an automatic ranging, polarity, and decimal placement and with an accuracy of 0·1% on any of the three ranges which are 0·01 to 9·99, 10·0 to 99·9, and 100·0 to 999·0 V d.c. The average reading time is 0·7 sec.

In operation, the input voltage is compared to the voltage from a Kelvin-Varley potentiometer and any difference actuates

stepping switches until a balance is achieved enabling the measured voltage to be presented digitally in the form of ⅝ in. high illuminated numerals in a 1½ in. by 5½ in. display area. The reference voltage is from a bank of mercury cells. Stability is achieved by the use of a transistorized amplifier and high grade choppers, the accuracy of the instrument being unaffected by mains variation. Printed circuitry has been extensively used to ensure reliability.

The instrument has been adapted so that a printing device can be coupled to it, and a printer is at present under development. It is also possible to have a remote read-out so that the indicator unit can be located in any suitable position, if necessary at a distance from the voltmeter or other digital instrument. An a.c. to d.c. converter is also under development. The voltmeter is made by Ferranti Ltd who claim that it is the first to be put into quantity production in the UK.

Tick **No 170** on reply card

WIRE-WOUND POTENTIOMETERS
for analogue computers and servos

The details of a range of precision wire-wound potentiometers have been released by Kynmore Engineering Co Ltd. The potentiometers are made to Kynmore specification AGS–1000. Up to 10 gangs can be mounted on a common spindle and the phase between gangs is claimed to be accurate to $\pm$ 0·075% at the electrical mid-point. Potentiometers may also be supplied with all gangs providing volts-output synchronism within 0·4%. The inertia of each system is of the order of one g-cm^2 and striction torque can be down to 1 g-cm/gang. The standard linearities are between 0·1 and 0·2% and the resolution on 50 and 100 kilohm types is of the order of 0·05%. The loading on each gang is up to 3 W depending upon the type. Dynamic noise levels are down to 10 mV at 1 mA wiper current and the equivalent noise resistance = 0·1% of total resistance or 10 ohm, whichever is the greater. The potentiometers can be supplied as build-in units or as complete potentiometer drive units. Types mounted coaxially with AK potentiometers (0·05% linearity high resolution) or CB units (10-turn potentiometers) are also available.

Tick **No 171** on reply card

SPARKLESS SWITCHES
for use in dangerous situations

A new range of resilient sparkless switches is now being produced specially designed for circumstances where pollution from the atmosphere, fire and explosion risks are present. The switches, which employ no springs of any kind, consist of a mercury tube mounted on an insulated carrier held on a spindle bonded in rubber to an anchor ring. To this ring a plate is fitted which determines the function of the switch to provide either a latching effect (when used as lighting switches or other applications where a positive 'on' position is required) or non-latching when used to replace a push button control for remote operation. These switches can be supplied in dustproof enclosure heavy duty boxes with shields and engraved plates and standard assemblies are available for 1 to 4 gang units and can be fitted with any combination of 1 to 4 sub-assemblies. The mercury switches are suitable for 8A starting current and 1A running current on 440 V supplies and when used on 250 V supplies are rated at a maximum of 15 A.

The switches are manufactured by Westool Ltd under licence from ICI Ltd.

Tick **No 172** on reply card

TEMPERATURE RECORDER
transistorized, four-point

Fielden Electronics Ltd have announced their new transistorized four-point temperature recorder. This has a 10 in. diameter chart and operates from the normal

Has had extensive field trials

50 c/s mains supply, Resistance bulbs are used as the temperature sensitive elements and low range spans are easily achieved. The use of transistors has reduced the power dissipated in the instrument and is claimed to have resulted in improved performance and greater reliability. Particular features are the improved stability control and the high reproducibility. The instrument is also available as a single point recorder with electrical or pneumatic control.

Tick **No 173** on reply card

The Aircraft Components and Connector Division of Thorn Electrical Industries Ltd have brought out a series of sliding rack connectors for use with racked components in console equipment.

Tick **No 174** on reply card

INDUSTRIAL PUBLICATIONS

Metro-Vick's **Principal Products** contains brief notes on all their products, including control gear, electronic equipment, non-destructive testing equipment and scientific apparatus. **175**

The encapsulation of electrical components by **Araldite** is practically shown in a Ciba (ARL) leaflet. **176**

From Ampex: details of their FR-300 **digital tape handler** and amplifiers and clock delay units. **177**

Texas Instruments' **Semiconductor Application Report** gives considerable technical detail of d.c. power supply circuits using silicon rectifiers. **178**

Up-to-date information from Chamberlain & Hookham on **protective relay** for over and phase unbalance protection. **179**

Timing equipment from Electrical Remote Control in a number of variations: flame-proof (Buxton certificate) electrical timing and control equipment, multi-circuit mercury tube timer, miniature synchronous cam operated timer, electronic process timers, cyclic timers, delay switches and automatic tea-break timer. **180**

Specification of two GEC **induction digitizers** also outlines operation, construction and applications. **181**

The range of Negretti & Zambra **hygrometers** is conveniently summarized in a revised catalogue; includes wet and dry bulb tables. Also available, a revised catalogue in the same style on their indicating, recording, vacuum, pressure and differential **gauges**, with lists of spares and accessories. **182**

For easy reference, sheets on the Hilger & Watts **digitizers** and allied equipment for data-processing are brought together in one folder. **183**

A collection of information on their **Helipot** comes from Beckman Instruments Ltd. **184**

Hallam, Sleigh and Cheston have information and drawings on their Widney Dorlce versatile prefabricated **cabinets** to house standard 19 in. instruments. **185**

Some applications of **tin** of interest to the electrical industry are noted in the 1958 Annual Report of the International Tin Council. **186**

Motor control centres, which are extensible and have withdrawable panels, are featured in an Igranic booklet. **187**

For further information on any industrial publication tick the corresponding number on the prepaid reply card on page 117

Tick **No 54** on reply card for further details

NOW—a moving coil relay for tough industrial use

MOVING COIL RELAY Type SB2

This robustly made relay will stand up to the wear and tear of industrial use. It is proof from damage by shock or vibration and the floating bearings ensure long life and reliability. The powerful coil movement gives a high contact pressure and the contacts themselves, gold mating on platinum, can be adjusted from outside over the whole scale.

Proof voltage between contacts, coil frame and earth—500 V.A.C. Maximum contact voltage 30 v. Insulation resistance: 10,000 MΩ min. between contacts, coil frame and earth.

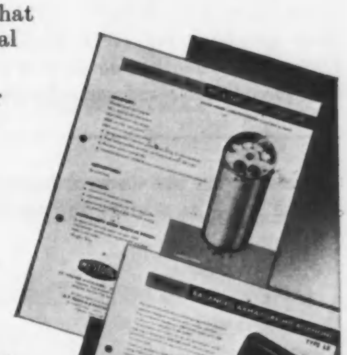
Photograph showing actual size.

and a balanced armature miniature microphone that's 'MADE IN GT. BRITAIN'

MICROPHONE Type LE

This microphone incorporates the design and manufacturing skill that is characteristic of all Besson micro-components. And the financial advantages over imported microphones are obvious.

The Type LE. Microphone is designed to operate with transistor amplifiers and will match into the average transistor which may have a resistance of 1,500—3,000 ohms. The microphone impedance is 3,000 ohms measured at 1,000 cycles and the resistance is 360 ohms. It is made to operate within a temperature range of 20 to 115°F, but can be specially treated to operate at much higher temperatures if required.



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TIB 114

For your bookshelf

Switching, Skipping and Scepticism

Switching Circuits with Computer Applications *by* **W. S. Humphrey, Jr.** *McGraw-Hill. 1958. 272 pp. £3 6s.*
Switching Circuits and Logical Design *by* **S. H. Caldwell** *John Wiley: New York. Chapman & Hall: London. 1958. 693 pp. £5 12s.*
★ 231

Of these two books, Mr Humphrey's is the elementary one, and the early chapters could be used as a school textbook, but for the esoteric nature of the subject. Permutations and combinations are treated, and elementary probability, but the reader for whom this material is intended is likely to be baffled later on, for example, to learn that 'superconductors' are bilateral elements, with no explanation whatever of what is meant by a superconductor. There is a large number of examples, but the principles they illustrate are not well brought out, particularly for iterative and sequential networks. Probably the number of readers will be a rapidly decaying function of the page number.

Professor Caldwell's book, on the other hand, is likely to hold the attention of even a sophisticated reader; we may think of an electrical engineer, sceptical about the value of Boolean algebra in circuit design. He will not be impressed by the applications of the subject mentioned in Chapter 1 (and virtually omitted by Humphrey), and will skip the descriptions of types of relays in Chapter 2. In Chapter 3, switching algebra is applied to produce further simplifications of simple networks, and our sceptic will be intrigued. By the end of Chapter 8, when the economical design of combinational contact networks has been intensively dealt with, he will be ready to admit that his circuit sense is not really just as good as the symbolic methods. He will, however, have shifted his ground, to complain that relays are old-fashioned, and will be wondering whether the material has, in fact, as much relevance to modern switching elements as the author has promised.

Chapter 9 on 'Electronic and Solid-State Devices in Combinational Switching Circuits' is not exhaustive enough to be really convincing. It is a pity that this could not have been placed at the beginning of the book, to allow some of the numerous illustrative examples in Chapters 4–8 to be put in terms of something other than relays. After a chapter on codes, the return to relay circuit examples for iterative networks and sequentially operating circuits will probably strengthen the sceptic's cynical suspicions, and not until the last two chapters will these be partially dispersed. The author could still further improve a good book by allowing the reader to omit, at his discretion, the portions of the material that apply primarily to contact networks. Of the rest of the material, the instructions for formulating clear design specifications for sequential circuits deserve special commendation. There are, however, some surprising lapses; definitions are omitted, or unreasonably deferred, for *series-parallel circuits, planar circuits, disjunctive properties, symmetric functions*, and *primitive connexion matrices*. G. C. TOOTILL

Work of quality

Automatic Measurement of Quality in Process Plants *edited by* **G. D. S. MacLellan.** *Butterworths Scientific Publications. 1958. 331 pp. £2 10s.*
★ 233

This is a collection of papers and discussions at a conference held by the Society of Instrument Technology in 1957. No emphasis need be given to the importance of the subject-matter. Every process designer realizes the necessity to measure product quality and the gaps which exist between laboratory techniques and process plant instrumentation for continuous sample or in-line stream analysis. The con-

ference tried to collect accounts of work being done in six main fields, corresponding to the sections of the book.

Section 1 is on adapting laboratory techniques to plant measurement and automatic sampling and testing, with particular reference to distillation, crystallizing and redox. The second section deals with gas analysis, emphasizing continuous stream sampling. Discussion of liquid stream analysis and spectrometric methods forms the subject of the next two sections.

In Section 5 appear some new techniques, such as nuclear resonance, mass spectrometry, vapour phase chromatography and X-ray fluorescent spectrometry. A miscellany of very practical papers make up the last Section: these illustrate the work on developing more exact analysis instruments for use under production conditions. Some of the subjects covered are viscometry in lubricating oil production and in resin polymerization, and nucleonic techniques for thickness, substance and specialized applications. The recorded discussions are disappointing: indeed it is difficult to believe that such stimulating papers evoked them.

The organizers are to be congratulated on a splendid effort and the publishers on their good workmanship. The book is a 'must' for all who would extend their knowledge in the cause of better process control.

B. W. BALLS

Only a phrase book

Dynamical Analogies *(2nd edition) by* **H. F. Olson** *Van Nostrand. 1958. 290 pp. £2 11s.* ★ 234

Dr Olson will need no introduction to acoustical engineers, who will be familiar with his *Acoustical Engineering*. In the present book he is concerned to point out the analogies that exist between electric circuits and dynamical systems generally, both acoustical and mechanical. Because of the existence of these analogies the whole of the well-developed theory of electric circuits becomes applicable to some problems in acoustical and mechanical engineering. The difficulty is that the different sorts of engineer talk different languages; how is the electrical engineer to convey his ideas to his brothers? As a dictionary this book will be of some help, for its first chapter explains the equivalence of inductance and inertia, capacitance and compliance, and so on. But the following grammar is very sketchy: an outline of Heaviside and an odd collection of theorems. Curiously, the really important idea that the electrical engineer has developed, that of the *circuit*, receives scant attention. For the rest, this is a phrase book—a collection of equivalent systems with summaries (without explanation or derivation) of the salient properties of each. The trouble with phrase books is that a slight misapplication can lead to disastrous results. And they do not tell you what you may *not* say.

P. L. TAYLOR

Selected Abstracts from The Journal of the Brit. I.R.E. 1946 to 1958 The British Institution of Radio Engineers. *1958. 72 pp. 3s. 6d.*

This is a booklet containing abstracts of selected items published in the *Journal of the British Institution of Radio Engineers*. They are classified by subject and arranged in numerical order of UDC number. There are sections on automatic control (621—52) and on automatic computers (681—142) which include a number of useful articles. For those who have the annual volumes of *Science Abstracts* to hand this new collection of abstracts is somewhat superfluous (though *Science Abstracts* has not covered all its entries). In itself it forms a helpful guide to some post-war articles and papers on radio and electronic engineering. ★ 235

Books received

Sampled-data Control Systems by Eliahu I. Jury. John Wiley: New York. Chapman & Hall: London. 1958. 468 pp. £6 8s. ★ 236

Transistor Electronics by Arthur W. Lo, Richard O. Endres, Jakob Zawels, Fred D. Waldhauer and Chung-Chi Cheng. Macmillan. 1958. 533 pp. £2 5s. ★ 237

★ Tick the relevant number on the reader information card for further information on any book reviewed above.

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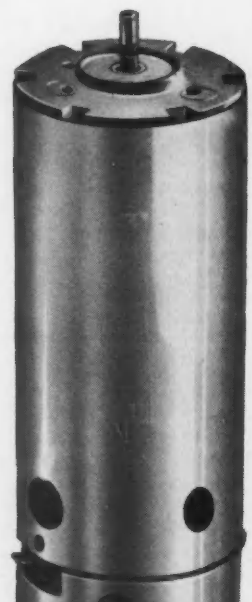

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